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USER COSTS ON THE I-15 DESIGN-BUILD RECONSTRUCTION

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UDOT RESEARCH & DEVELOPMENT REPORT ABSTRACT

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This study evaluates the impact of Salt Lake City's I-15 reconstruction on user delays. It compares user delays for three reconstruction alternatives between 1996 and 2010. The actual reconstruction of I-15 was carried out with the Design-Build (DB) alternative. Under DB, I-15 was completed in four and a half years. Design and construction were combined in a single contract. With the Traditional-Build (TB) approach, design and construction take place separately. The TB process is divided into 20-30 smaller contracts and lasts for ten years. The No-Build (NB) alternative did not increase I-15 capacity or involve any major maintenance during the study period. The alternatives were compared and DB was evaluated based on total user delays, travel times along the corridor, and average network congestion. The Wasatch Front Regional Council provided travel demand data for the study. The results show that any active construction alternative is better than no construction. DB was better than TB in all performance measures.</td></tr>
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ACRONYMS

AADT	Average Annual Daily Traffic
ADT	Average Daily Traffic
ATR	Automatic Traffic Recorders
BPR	Bureau of Public Roads
DB	Design-Build
DBB	Design-Bid-Build
E-W	East-West
HOV	High Occupancy Vehicle
I-15	Interstate 15
I-215	Interstate 215
I-80	Interstate 80
MD	Mid-day
MOE	Measures Of Effectiveness
MOT	Maintenance Of Traffic
NB	North-bound
N-B	No-Build
N-S	North-South
OD	Origin Destination
SB	South-bound
SDEIS	Supplemental Draft Environmental Impact Statement
TB	Traditional-Build
TIP	Transportation Improvement Plan
TSM	Transportation System Management
UDOT	Utah Department Of Transportation
UTL	Utah Traffic Lab
V/C	Volume/Capacity
VHD	Vehicle Hours of Delay
VMT	Vehicle Miles of Travel
WFRC	Wasatch Front Regional Council

1. INTRODUCTION

1.1 Background and Scope of the Research

1.1.1 Need for the I-15 Reconstruction

The Salt Lake County section of I-15 was constructed in the 1960s as a part of the National System of Interstate and Defense Highways. It was designed to serve projected needs through the 1980s. By the end of the 1980s, traffic demands far exceeded freeway capacity. I-15 was deteriorating and did not meet design/safety criteria [24].

The Wasatch Front Regional Council (WFRC) began the I-15/State Street Corridor Study in 1984 to determine future transportation needs [24]. State Street had served for decades as a main north-south route in Utah. The study concluded that both I-15 and State Street required significant improvements.

In 1986, the WFRC began an Environmental Impact Study (EIS) of alternative highway and transit improvements. It considered 33 alternatives and narrowed this number to 12. The Utah Transportation Commission (UTC) accepted Alternative 11 in July 1990 [24]. Alternative 11 built a light rail system along the Union Pacific Railroad from Sandy City to downtown Salt Lake City. It involved expansion and reorientation of the bus system. It also added two general-purpose lanes to I-15 in each direction and improved I-15 interchanges. Two significant changes were later made to Alternative 11. The passage of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) encouraged adding High Occupancy Vehicle (HOV) lanes to I-15. Therefore, the Utah Transportation Commission decided that one of the two additional lanes in each direction should be a HOV lane.

After accepting the Draft Environmental Impact Statement (DEIS), the highway and transit portions of the projects were separated. The transit improvements were the Utah Transit Authority's (UTA) responsibility. Highway improvements were under jurisdiction of the Utah Department of Transportation (UDOT).

Two corridor studies ran concurrently in 1994. The General Development Plan (GDP) provided basic concepts for the widening, upgrading and rebuilding 16 miles of I-15. Parsons Brinckerhoff Quade & Douglas, Inc. carried out the plan [25]. The Supplemental Draft Environmental Impact Statement (SDEIS) used the GDP in its analysis of four reconstruction alternatives:

1. No-Build (NB) – Planned transportation improvements in the region would be implemented. Structural and pavement deficiencies on I-15 would be corrected.
2. Transportation System Management (TSM) – Same as NB. In addition, ramps would be widened and metered, stripes would be modified, and one major interchange would be improved.
3. The full build – General purpose and HOV lanes would be added. Interchanges and frontage roads would be reconstructed. Auxiliary lanes and collector-distributor roads would be added. Other related improvements would follow.
4. The partial build – The concept was similar to full build without the addition of a general-purpose lane.

These alternatives were discussed publicly. The third was selected as the most viable solution for I-15 improvements [24]. It could be carried out by either the Design-Build (DB) or Traditional-Build (TB) method.

1.1.2 Selection of the Design-Build Contracting Method

The Design-Build (DB) construction method was selected for I-15 reconstruction instead of the SDEIS full build method. DB removed and replaced 16 miles of urban I-15. It made the following changes:
Widened roadways from six to twelve lanes.
Rebuilt 137 structures/bridges, including three Interstate to Interstate junctions and eight Single Point Urban Interchanges (SPUI).
Implemented corridor and valley-wide Advanced Traffic Management Systems (ATMS).
Implemented grade-separated railroad crossings.
Built HOV lanes.
The UDOT executive director decided in 1996 to rebuild I-15 using DB. This decision followed consultation with the governor and the local chapter of the Associated General Contractors [27]. Two timing issues influenced the decision. First, the public strongly supported timely I-15 completion so as to minimize traffic congestion on alternate routes. Second, DB would complete reconstruction before the 2002 Winter Olympic Games began in Salt Lake City.
Quality and cost factors also influenced reconstruction method selection. UDOT wanted a well-designed, reliable, durable, high-quality highway. This would minimize future liability and maintenance expenses. It would also serve the needs of users.
State procurement laws were modified in order to make DB possible. They granted the state permission to award the I-15 contract to a firm offering the 'best value' proposal even if another firm provided a bid with a lower initial cost [27].
UDOT recognized the following benefits of the DB contracting method [27]:

One contractor would be responsible for all design and construction work.
No management interface between the design and construction segments of the project.
Improved risk management with reduced change orders and claims.
Time savings as design and construction occur simultaneously.
Cost savings resulting from increased efficiency of design and construction, standardization, and fewer uncertainties and contingencies.
The project could be innovatively specialized to meet the particular demands of I-15.

1.2 Scope of the Research

1.3 Reconstruction Alternatives Considered in the Study

This study considered DB, TB, and NB for the reconstruction of I-15. These alternatives were compared under the following terms:
Major capacity improvements on roads other than I-15 occurred only until 2001.
The light rail influenced the number of private car trips.
No changes occurred in the other public transit services.
No additional capacity improvements were considered in order to mitigate traffic on I-15 after 2001.
DB and TB also improved the capacity of some streets parallel to I-15 to ease traffic during reconstruction. NB implemented no such changes.

1.4 Study Timeframe

The study period extends from 1996 to 2010 and assumes that both DB and TB reconstruction begin in 1997. DB ends in 2001 and TB ends in 2006. Both projects create the same I-15. Table 4.1 shows the time frame used in this study.

Table 4.1: I-15 reconstruction impacts study timeframe

Alternative	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
N-B	No Construction										
DB	Design	Design & Construction					No Construction				
TB	Design	Design & Construction								Construction	

The I-15 DB reconstruction project disrupted traffic in Salt Lake County for about four and half years. Construction would have lasted for ten years with the Traditional-Build (TB) alternative. Two main factors differentiated DB from TB. First, DB was developed under a single contract while TB required up to thirty different contracts for design and construction. Second, DB efficiently combined design and construction. Construction began immediately after completion of the initial design. A section was designed at the same time one was being built. TB required that the entire design be completed before any construction began. Because TB occurred under the direction of many entities, the probability of coordination problems among design and construction entities was substantially higher than with DB. These problems cause delays in construction time.

This study asks whether user costs are higher with DB or TB between 1996 and 2010. The NB method would not involve any reconstruction or maintenance work on I-15 during the study period. Therefore, NB mainly serves as a baseline to determine when the benefits of DB or TB match or exceed NB.

The study addresses three null hypotheses associated with total user delays between 1996 and 2010:

1. $H_{0(1)}$ - The total user delays are higher for DB than for NB over the study timeframe.
2. $H_{0(2)}$ - The total user delays are higher for DB than for TB over the study timeframe.
3. $H_{0(2)}$ - The total user delays are higher for TB than for NB over the study timeframe.

1.4.1 Research Tasks

The three major study tasks are:

1. Model the region-wide traffic delays, travel times, and network congestion on I-15 for DB, TB, and NB over the study timeframe.
2. Compare user delay costs, travel times, and network congestion for DB, TB, and NB.
3. Draw conclusions based on user delay costs, travel times and network congestion for DB, TB and NB.

1.5 Report Organization

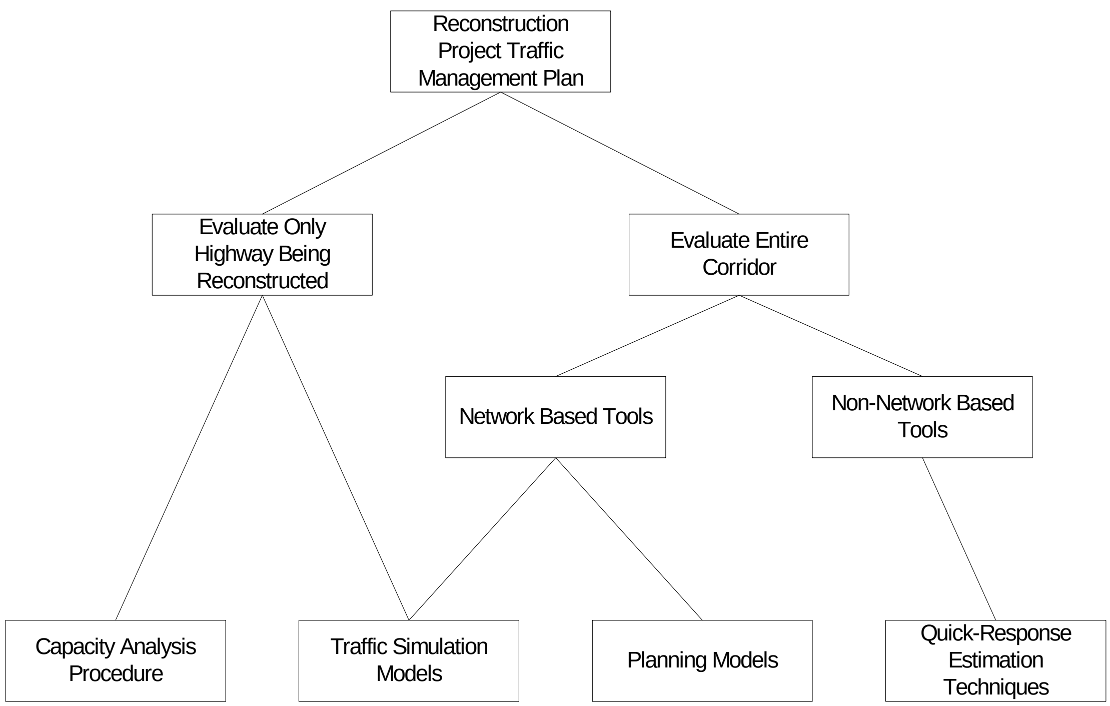
The report is divided into eight chapters. Chapter 2 provides a comprehensive literature review. It concentrates on methodologies for transportation management during road reconstruction, recent DB contracting experiences, and case studies of major highway reconstruction projects. Chapter 3 discusses the background of the I-15 project. Chapter 4 explains the model methodology, study area, timeframe, model structure, and required modeling data. Chapter 5 explains calibration of the model. It provides detailed explanations of adjusting field data and calibrating software parameters. Chapter 6 describes traffic assignment modeling for DB, TB, and NB. Chapter 7 compares DB, TB, and NB in terms of their Measures Of Effectiveness (MOEs). Chapter 8 discusses the modeling for DB, TB, and NB. Chapter 9 presents conclusions from the research and recommends areas for future research. Chapter 10 describes traffic accident analysis for three reconstruction alternatives. Finally, Chapter 11 deals with emission inventories associated with different reconstruction alternatives.

2. LITERATURE REVIEW

The following studies summarize transportation management strategies, guidelines, scheduling techniques and evaluations. The basics of these studies can be applied to any freeway reconstruction project. However, each project has unique needs and reveals useful information for future reconstruction projects. Studies carried out under DB are discussed. However, there is no comprehensive study that describes the type of project that would best be met my DB.

2.1 Review of the Transportation Management Studies

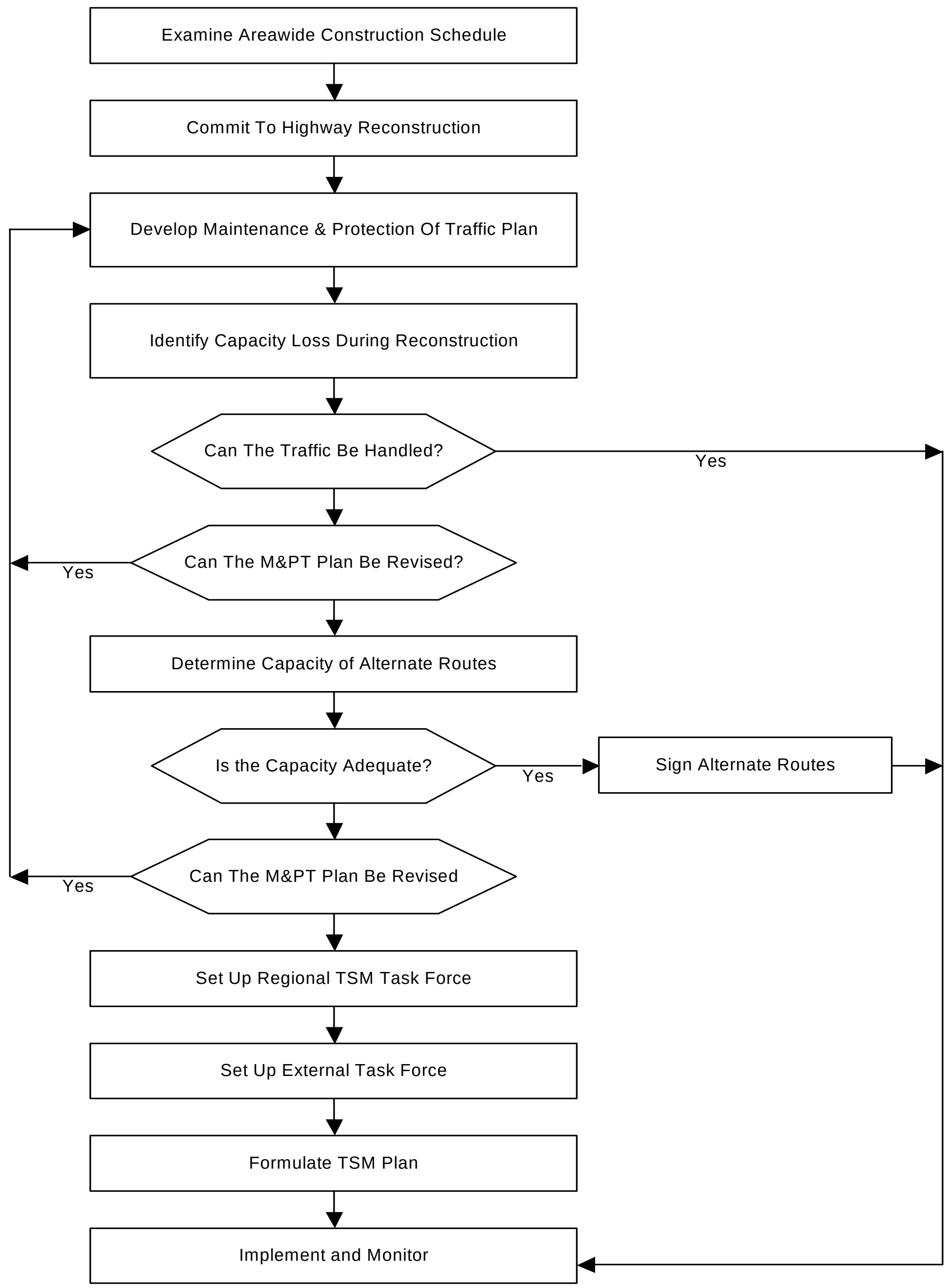
Major highway reconstruction has significant impacts on the drivers. The impact increases when the rest of the urban transportation network cannot accommodate traffic that diverts from the highway [11]. Many researchers have conducted studies that evaluate the travel impacts of highway reconstruction projects. Krammes [11] recognized a highway as a scarce resource that should be carefully balanced between motorist use and reconstruction activities. Figure 2.1 summarizes his steps and guidelines for evaluating travel impacts.



Source: Krammes [11]

Figure 2.1: A decision tree for the reconstruction project travel impact evaluation

Reproduced with permission from the American Society of Civil Engineers. From R.A. Krammes. Travel Impact Evaluation for Major Highway Reconstruction Projects. In Journal of Transportation Engineering Vol.116 No.1, American Society of Civil Engineers, 1990, Figure 2, p.77.



Source: Neveu et al. [13]

Figure 2.2: TSM planning process by NYSDOT

Reproduced with permission from the Transportation Research Board. From A.J. Neveu and L.Maynus. A Planning Process To Develop Traffic Management Plans During Highway Reconstruction. In Transportation Research Record 1081*, Transportation Research Board, National Research Council, Washington, D.C., 1986, Figure 1, p.56.*

Herbsman [14] discusses scheduling procedures for highway construction. He proposes several scheduling techniques that should be selected based on project characteristics. He also emphasizes the importance of determining a reasonable contract duration. Herbsman believes that efficient scheduling techniques benefit the sponsoring agency, motorists, and the contractor. For fast track applications he recommended high incentives, penalty clauses, and bidding on performance time in order to expedite project completion.

Neveu et al. [13] developed a manual of traffic management plans used by the New York State Department of Transportation (NYSDOT) as a guideline for TSM actions. The manual presents a procedure for identifying reconstruction projects that might need TSM strategies in order to maintain traffic flows at an acceptable level. It also describes specific TSM actions for traffic management. This information comes from experiences with TSM strategies in Pittsburgh, Syracuse, and Boston reconstruction projects. Figure 2.2 shows a flowchart of the planning process for formulating a TSM plan.

Choocharukul et al. [15] developed a methodology for evaluating the cost-effectiveness of congestion mitigation projects. It addresses travel time savings, vehicle operating cost savings, crash cost savings, and emission reductions. The methodology involves congestion management actions such as road widening, HOV facilities, ramp metering, and incident management for long-term construction projects.

2.2 Review of the Design-Build Evaluation Studies

Many contracting agencies are interested in using DB. They want a guideline that outlines when and where DB provides greater benefits than TB. A survey conducted by Design-Build Institute of America in 1997 found that nearly 16 billion dollars worth of projects in the last 12 months were procured by contractors using DB [8].

Gransberg et al. [8] suggests three ways Departments of Transportation can select a contractor to perform DB services: low-bid DB, adjusted score DB, and best value DB. Generally, the low-bid approach is preferred for projects with a clearly defined scope. Adjusted score works well when the final outcomes are clearly defined, but all alternatives could provide the desired outcomes. The best value method works for projects that encourage new technologies and innovations. The study indicates the strengths and weaknesses of all three DB approaches. It shows DB as a successful method for highway and other transportation projects.

Ellis et al. [1] described the Florida Department of Transportation's experiences with 11 projects that were part of the pilot DB program. The University of Florida compared the pilot program with TB projects. They found that, on average, DB took 21.1 percent less time to complete a project than TB. DB design time was, on average, 54 percent lower than the TB design time.

Ernzen et al. [5] described the partnering of the Arizona Department of Transportation, the DB construction team, and the public to reconstruct an urban freeway in Phoenix. This project was similar to the I-15 reconstruction project. It increased an eight-mile stretch of a freeway from six lanes to ten lanes by adding a HOV lane and an auxiliary lane. This paper was written while the project was being carried out. The authors recognized no problems with project completion. All partners in the project were satisfied with the process.

2.3 Review of the Highway Reconstruction Case Studies

Tadi et al. [17] assessed the impact of the Lodge Freeway (US-10) reconstruction on surface streets in Detroit. The northbound freeway was completely closed while the southbound remained open and vice versa. Traffic volume, average speed, and travel time data were collected on four alternative routes capable of handling diverted traffic. The study concluded that comprehensive planning should be carried out among the involved agencies. Extensive communication with the public should also be carried out before and during construction.

Dudek et al. [18] studied traffic capacity on urban freeway work zones in Texas. They found that hourly capacities of urban freeways depend on the actual number of lanes open during construction. Capacity per lane increased when more lanes were open in the work zone. The study showed how data could be used to estimate capacity effects of lane closure. These estimates help mitigate a lane closure's impact on traffic.

Wildenthal et al. [2] performed a study to determine the user costs and benefits of widening an urban highway. Traveler benefits were divided into three categories: delay savings, accident reductions, and vehicle operating cost savings. Delay savings were estimated by the reduced number of stops along the study section. Heem-III benefit-cost model calculated vehicle operating savings. A statistical analysis compared the number of accidents prior, during, and after the project. The cost ratio of 7.2 indicated considerable user benefits over the costs of the highway improvement.

Hendrickson et al. [16] described traveler responses to the Parkway East (I-376) reconstruction project in Pittsburgh. Travelers could change mode of travel, switch to off-peak hours, use alternative routes, change destinations for certain trips, or even reduce the number of trips. The study found that significant diversions did not occur due to temporary traffic restrictions. Most driver modifications involved taking alternate routes or traveling during off-peak periods.

Benz et al. [4] discusses the I-45 Pierce Elevated Freeway reconstruction. It was popular with the public and economically successful. The study focuses on pre-construction traffic modeling and on public information and data collection before, during, and after the construction. It also emphasizes traffic engineers' responsibility to provide information to the travelers that will optimize their use the transportation network.

Kremer et al. [20] evaluate construction staging plans. Their study methodology incorporates traffic engineering analysis and develops simulation models to evaluate two alternative staging schemes. A trial evaluation of the results was carried out during the simulation process. The evaluation validated the results of the traffic simulations.

3. I-15 PROJECT BACKGROUND

3.1 I-15 Design-Build Project

The I-15 project reconstructed of all of the interchanges, several railroad grade separation structures, and the 400 South, 500 South, 600 South, 600 North and 900 South viaducts leading in and out of the Salt Lake City central business district [27]. Numerous frontage roads and local streets were modified and relocated or reconstructed [25]. One new interchange was added at 400 South. All existing interchanges and junctions were significantly reconfigured. Most local street interchanges were converted from diamond configuration to single point urban interchanges. Modifications were carried out at these locations:

The reconstruction modifications included:

I-215 in the vicinity of 6400 South between State Street and 700 West.

I-80 in the vicinity of 2400 South between State Street and I-15.

State Route 201 from I-15 to a point just west of the Jordan River crossing.

I-80 in the vicinity of North Temple from I-15 to 1000 West.

The project also cleared and removed existing highway structures, constructed noise walls and retaining walls, constructed a drainage system, introduced landscaping and aesthetic treatments, placed signing and pavement markings for all new pavements, built new traffic signals and modified existing traffic signals, and placed traffic control and safety devices.

3.2 Pre-construction Analyses

3.2.1 I-15 Corridor Traffic Report

The 1996 I-15 Corridor traffic report summarizes current and projected traffic volumes for the I-15 segments considered for reconstruction (500 N to 10800 S; the report did not consider 600 N). The report summarizes traffic data available through February 1996. The data was divided into four sections: mainline travel speeds, mainline vehicle occupancy, traffic accidents, and vehicle mix information. The report also contains data about traffic volumes and the level of service for interchanges being considered for reconstruction. The interchanges are:

10600 South (Diamond Interchange to SPUI)

9000 South (Diamond Interchange to SPUI)

7200 South (Diamond Interchange to SPUI)

South Junction (I-15 / I-215)

5300 South (Diamond Interchange to SPUI)

4500 South (Diamond Interchange to SPUI)

3300 South (Diamond Interchange to SPUI)

2400 South Junction and SR-201 Interchange

900 West at SR-201 (Diamond Interchange to SPUI)

1300 South

900 South

500 and 600 South

400 South – HOV access to/from the freeway and access to I-15 N

West Junction (I-15 / I-80)
600 North (Diamond Interchange to SPUI)
This study used the I-15 corridor traffic report for its layout of reconstructed interchanges.

3.2.2 Parallel Streets Study

This study was a product of the I-15 Corridor Management Consultant activities. It became part of the I-15 corridor SDEIS. Parsons & Brinckerhoff conducted the study and provided significant input for the Traffic Management Plan for I-15 [26]. The study evaluated the ability of the streets parallel to I-15 to serve as detour routes during I-15 reconstruction. It proposed several improvement alternatives for the streets.

The study found that reduced corridor capacity during reconstruction would not satisfy travel demand. Around 3600 vehicles per peak hour in peak direction would have to divert from the I-15 corridor onto other surrounding parallel surface streets.

The General Development Plan [25] for this project identified 700 East, State Street, Main Street, and Redwood Road as potential detour routes. 300 West, West Temple, 500 and 700 West and 1300 West were also considered in the study. The existing conditions and possible improvements for each detour route were determined. At the time of the study no improvements were anticipated for major existing roadways on the west side of the I-15.

The study next compared future traffic volumes with the capacities of detour streets. The authors used travel demand management programs to determine whether projected traffic volumes would outmatch the street capacities.

The parallel streets study recommended three improvement scenarios for detour streets. Figure 3.1 shows the minimum improvements required for streets to serve as detour routes during I-15 reconstruction. The link networks for building alternatives were configured according to these improvements. The NB alternative did not assume these improvements. They were not general road improvements that would happen regardless of the I-15 reconstruction.

Section	Length in km (mi)	Existing Lanes1	Proposed Lanes	Estimated Cost ($ M)	Notes
700/900 EAST					
3300 South - 4800 South	2.7 (1.7 mi)	3T,L	4T,L	4.6	Construct 2 lanes in existing median
7200 South - 9400 South	5.1 (3.2 mi)	1-2T, 0-1L	3T, L	10.4	Part of TIP Project
Subtotal estimated cost				$ 15.00	
STATE STREET					
Section	Length in km (mi)	Existing Lanes1	Proposed Lanes	Estimated Cost ($ M)	Notes
400 South - 3000 South	4.7 (2.9 mi)	3T, L	4T, L	0.42	Re-stripe; prohibit parking
3000 South - 4260 South	2.3 (1.4 mi)	3T, L	4T, L	3.8	Construct 2 lanes in gutter; prohibit parking
4260 South - 5300 South	1.9 (1.2 mi)	3T, L	4T, L	0.17	Re-stripe; prohibit parking
I-215 - 7200 South	1.4 (0.9 mi)	SB: 2T; NB: 3T, L	3T, L	0.06	Re-stripe
Subtotal estimated cost				$ 4.45	
MAIN STREET					
Section	Length in km (mi)	Existing Lanes1	Proposed Lanes	Estimated Cost ($ M)	Notes
2100 South - 3300 South	2.3 (1.4 mi)	2T	2T, L	0.2	Re-stripe and prohibit parking
Subtotal estimated cost				$ 0.20	
WEST TEMPLE					
Section	Length in km (mi)	Existing Lanes1	Proposed Lanes	Estimated Cost ($ M)	Notes
500 South - 700 South	0.8 (0.5 mi)	2T, L	3T, L	1.4	Construct new lanes in park strip; no parking
Subtotal estimated cost				$ 1.40	-
300 WEST					
Section	Length in km (mi)	Existing Lanes1	Proposed Lanes	Estimated Cost ($ M)	Notes
900 South - 3300 South	4.3 (2.7 mi)	2T, L	3T, L	0.4	Re-stripe; prohibit parking
Subtotal estimated cost				$ 0.40	
REDWOOD ROAD					
Section	Length in km (mi)	Existing Lanes1	Proposed Lanes	Estimated Cost ($ M)	Notes
I-80 - S.P. Lines (1500 South)	2.3 (1.4 mi)	2T, L	3T, L	3.8	Reconstruct outside lane and prohibit parking
2100 South - 3100 South	1.8 (1.1 mi)	SB: 3T; NB: 2T, L	3T, L	0.17	Re-stripe and prohibit parking
3100 South - 5400 South	4.2 (2.6 mi)	2T, L	3T, L	0.37	Re-stripe and prohibit parking
6200 South - 6600 South	0.8 (0.5 mi)	2T, L	3T, L	0.06	Re-stripe and prohibit parking
Subtotal estimated cost				$ 4.40	
TOTAL ESTIMATED COST				$ 25.85	(Rounded to $25.9 million)

Notes:
T = Through, L = Center dual left turn lane, SB = Southbound, NB = Northbound
NC = No change
TIP (Transportation Improvement Program) and Long Range Transportation Plan improvements are identified by WFRC
[1]Existing lane configuration is in each direction unless otherwise noted
[2]TIP proposes 2T, L, but 25 m (82 ft) roadway can be re-striped to permit an additional travel lane (parking would be prohibited)

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PARSONS BRINCKERHOFF

Source: Parsons Brinckerhoff Quade & Douglas [26]

Figure 3.1: Potential street improvements proposed by Parsons & Brickerhoff

3.2.3 Wasatch Constructors’ Proposal – Maintenance of Traffic Plan

Wasatch Constructors was awarded the DB contract. It developed a comprehensive Maintenance of Traffic Plan (MOT).

This plan had seven strategies to ease travel on I-15 during reconstruction:

Alternative routes

Advanced Traffic Management System

Motorist information

Public information/outreach

Travel demand management

Incident management

Construction zone strategy

MOT presented an alternative route strategy to ease traffic congestion on the narrowed I-15 mainline and to divert traffic to surface streets and other freeways. I-215 was re-striped from three to four lanes from the South Junction (I-15 / I-215) to the junction between the I-215 and I-80 West. This part of I-215 was intended to serve as the main detour for most northbound traffic. The southern part of I-15 (up to 10600 S) was to be open throughout reconstruction except during the twelve-month closure for the reconstruction of the I-15/I-215 junction.

The MOT strategy relied on the arterial network’s ability to handle diverted traffic from I-15 [29].

Figure 3.2 shows the alternative freeway routes proposed by MOT. These basic detour strategies were used to develop a road closure plan during reconstruction. The area under construction was divided into three segments:

Cottonwood segment – 10600 South to 5300 South

Jordan segment – 5300 South to 1700 South

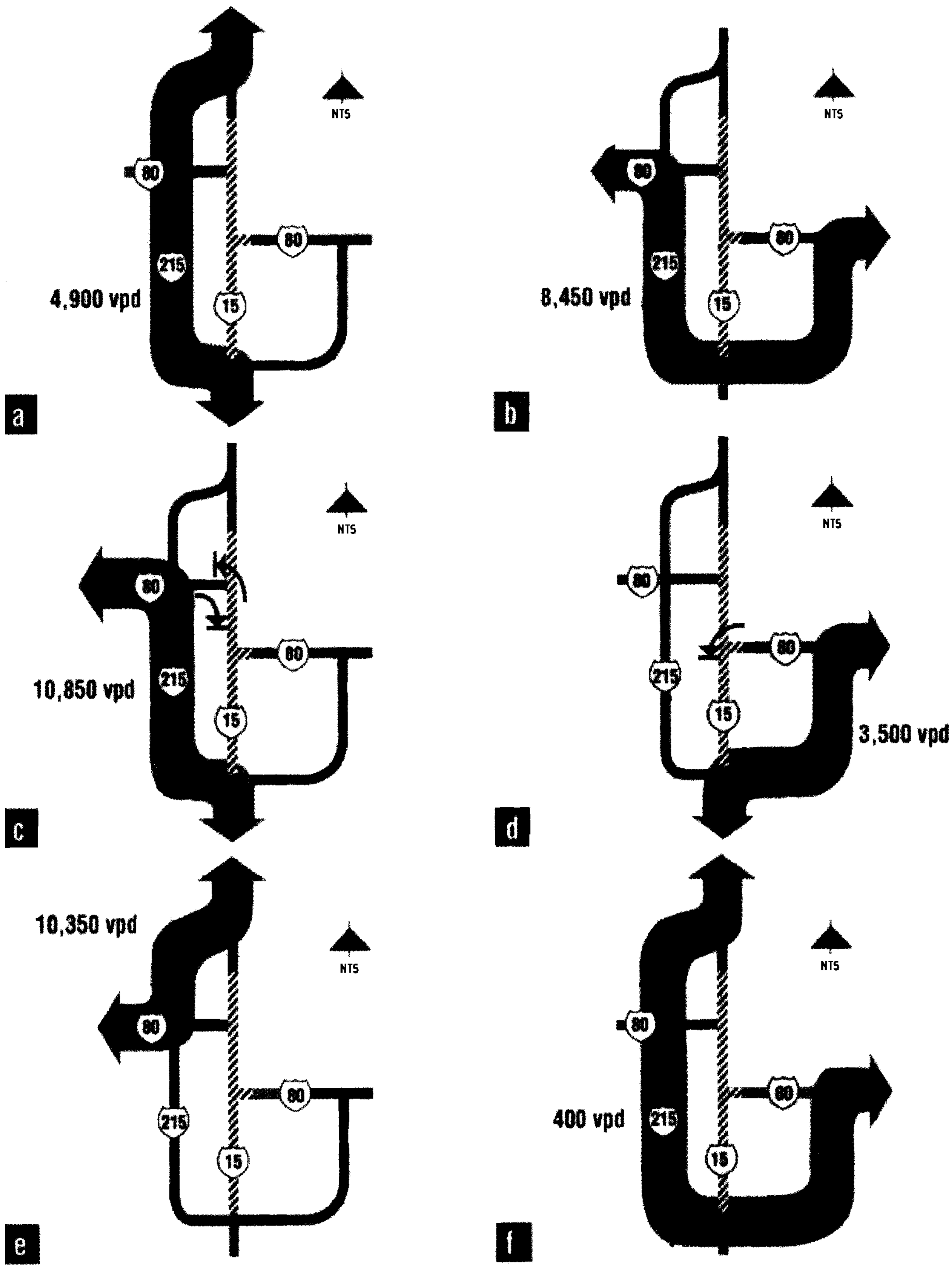
Downtown segment – 1700 South to 600 North

The construction work on each of these segments was divided into four phases:

1. Phase 1 – May 1997 through August 1997
2. Phase 2 – September 1997 through July 1999
3. Phase 3 – August 1999 through May 2001
4. Phase 4 – June 2001 through July 2001

The initial MOT plan was revised many times during reconstruction because of unexpected problems and opportunities to expedite construction. This study used the actual start and end schedules for closing activities. UDOT provided this data. Appendix D shows the complete list of closing activities.

UDOT, Parsons & Brinckerhoff, and Wasatch Constructors all seek to minimize the impact of construction on drivers. The I-15 Corridor Traffic Report, Parallel Street Study, and MOT plan assess street capacity and provide effective alternatives to ease the impact of reconstruction.



Source: Wasatch Constructors [29]

Figure 3.2: Alternative freeway routes and detours for through traffic

4. MODEL DEVELOPMENT

A model was developed to estimate the benefits and costs of the different reconstruction alternatives. The methodology used in this study is similar to the methodology used by WFRC in its previous transportation planning activities. A four-step transportation planning process is used to obtain Measures of Effectiveness (MOEs) such as user delays and travel times for DB, TB, and NB. The four steps are:

1. Set the highway network for a certain phase in the DB, TB, or NB process.
2. Load the relevant travel demand table for the zones considered in the network.
3. Run traffic assignments for the chosen network and chosen travel demand.
4. Process data using export and spreadsheet calculations.

Three of the four steps are completed at the Wasatch Front Regional Council (WFRC), a metropolitan planning organization. The WFRC provides the Utah Traffic Lab (UTL) with Origin-Destination (OD) travel demand tables. Figure 4.1 shows the simplified process of traffic forecasting used in this study. Figure 4.2 is detailed flowchart of the modeling procedure used to obtain MOEs for DB, TB, and NB.

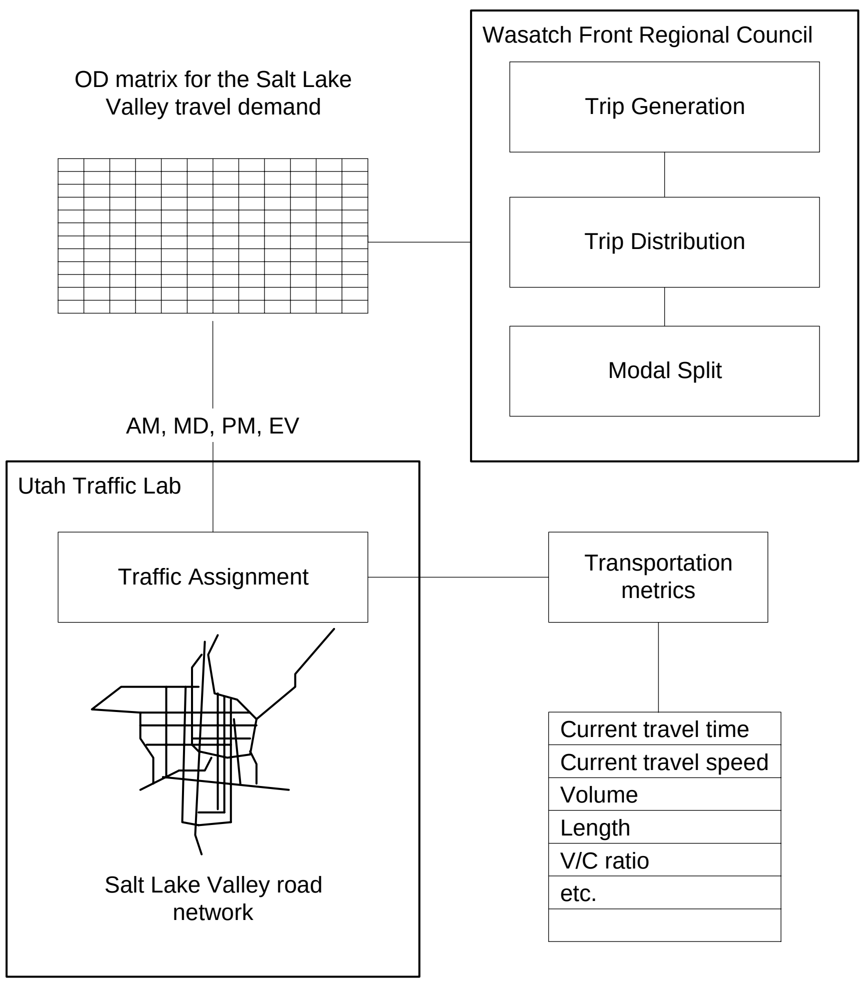


Figure 4.1: Simplified process of traffic forecasting used in the study

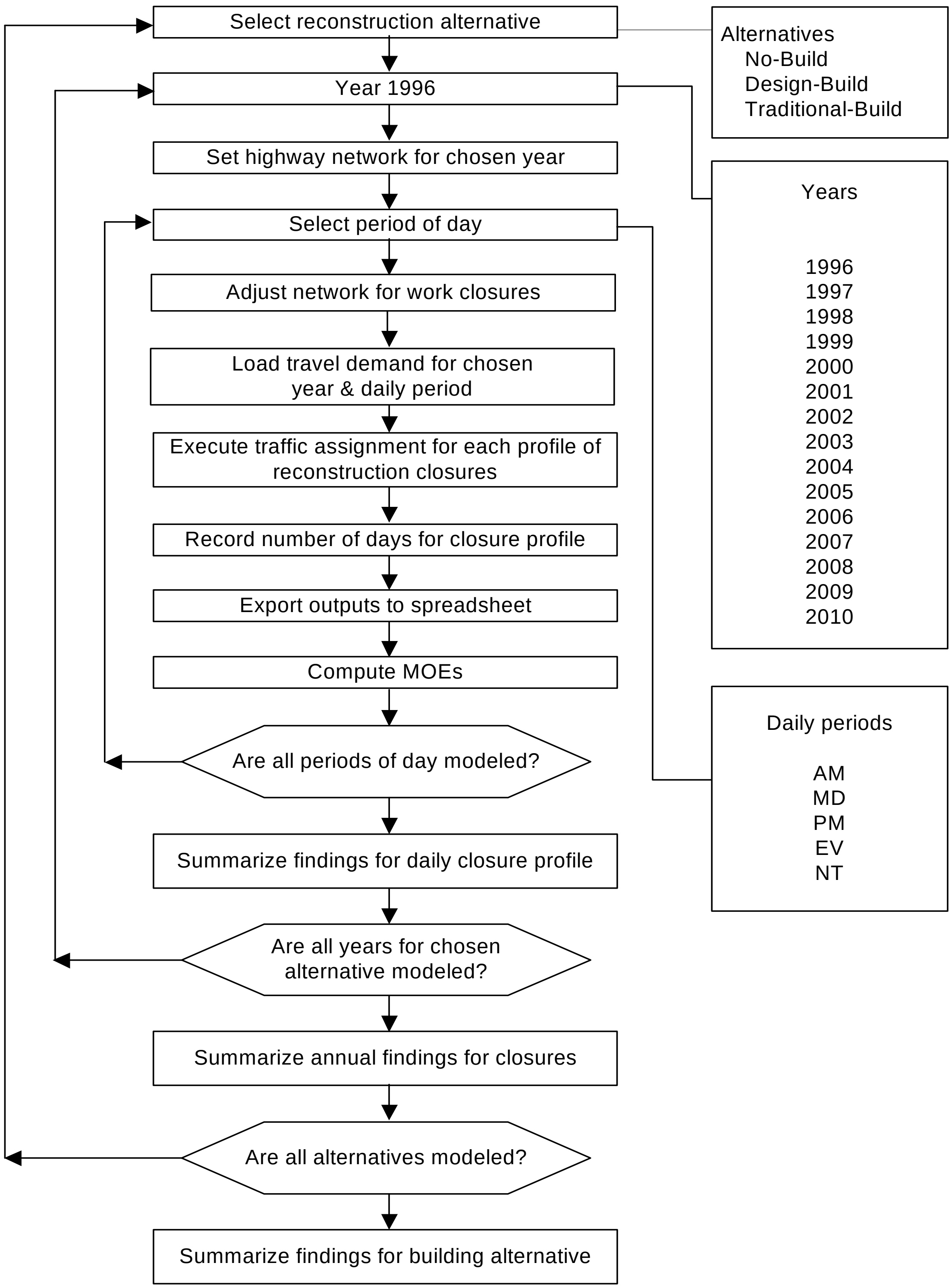


Figure 4.2: A procedure for modeling MOEs for the reconstruction alternatives

4.1 The VISUM – Traffic Assignment Software

4.1.1 Selection of the Modeling Software

TRANSCAD, TP+, EMME/2, VISUM, INTEGRATION, and PARAMICS were considered for modeling travel demand. These software all model data differently. Quality of traffic assignments was the most important software feature considered in selecting software for the study.

Software was compared according to these criteria:

Size of the network - number of nodes and links that can be handled

Available traffic assignment routines

Potential to export inputs/outputs to a microsimulation software

Number and variety of performance measures produced

Price of the software (discounts, academic versions, technical support)

User interface

Peer reviews on the weaknesses and advantages of the software

VISUM was selected because it satisfied the given criteria better than other software packages.

VISUM data is efficient as it can be directly exported to the VISSIM traffic simulation package. This feature gives the modelers an opportunity to use compatible traffic models to plan and operate traffic analysis. The University of Utah Traffic Lab owns the VISSIM model. Therefore, no additional costs were incurred. Also, the TP+ model data used by the WFRC can be converted to American Standard Code for Information Interchange (ASCII) format and imported into VISUM.

4.1.2 Basic VISUM Characteristics

VISUM is multimodal traffic assignment software. It is a module of the Planung Transport Verkehr AG (PTV AG) software package. VISUM models and measures trip generation, trip distribution, and modal split. These results are presented in an OD trip table in terms of number of trips during a certain period between each pair of zones in a region. VISUM 'reads' the table and assigns trips on the road network following parameters given by a modeler.

The traffic assignment depends on the capacity of each link in the network, its free flow speed, and its impedance (which can be set by the modeler). VISUM uses one of its several algorithms to assign trips on available network links. Usually, the calibration process requires that a modeler try all available assignment procedures in order to get link volumes as close as possible to real traffic loads on the links.

4.2 Study Area

The study area for this project is the entire road network in the Salt Lake Valley. The road network is comprised of freeways, principal and minor arterials, and collector roads. The area is bounded by 2300 North, SR-111, 14600 South, and I-215 East. Figure 4.3 shows the VISUM software output of the Salt Lake Valley road network. The darkest links represent freeways (I-15, I-80, and I-215), and the light-shaded links represent the principal arterials, the minor arterials, and the collectors.

4.3 VISUM Network Elements

A network model provides transportation supply data. This study initially considered two options for building the road network. First, the network could be completely torn down and rebuilt with about thirty main north-south and east-west corridors. It would consist of freeways, highways, and major arterials. The traffic analysis of I-15 reconstruction would be conducted based on this simplified network.

Second, the existing WFRC model would be used with transportation planning software called TP+. This network is more comprehensive than the first, but it is necessary to convert it from the TP+ format to the VISUM format. After the conversion, the VISUM network needs to be checked for any inconsistency (links, nodes, zones).

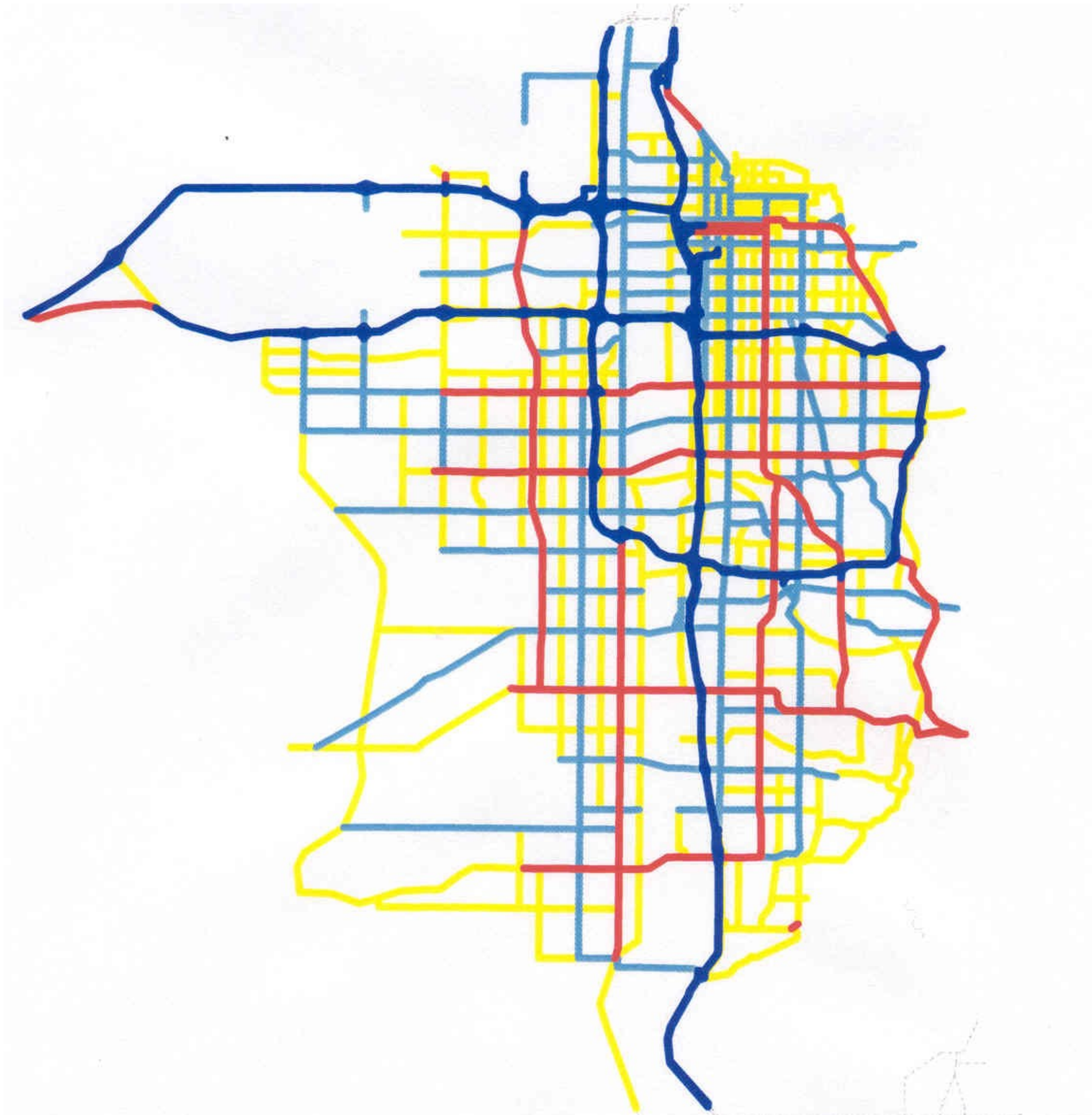


Figure 4.3: VISUM layout of the Salt Lake County road network

The second approach was selected. Although the conversion process was complex, it was expected to take less time than building a new network.

4.3.1 Nodes

Nodes usually represent intersections. They are usually the start and end points of links. However, some nodes are placed in the middle of the links. X and Y coordinates are necessary for defining nodes [37]. The WFRC model provides both coordinates and node numbers. Universal Transverse Mercator coordinates are used in both WFRC and UTL models. They express the distance between two points in meters. Transportation metrics produced by VISUM were originally in metric units but were later converted to English units and used for calculating MOEs.

4.3.2 Zones

VISUM divides land into zones depending on its particular use (residential areas, places of work, shopping centers etc.). Zones represent the origins and destinations of the trips in a region. They are connected to links. The TP+ software does not save zones as separate network objects, but the first nodes in the file usually represent the zones. The first 1400 nodes in the Salt Lake County node text file identify zones by with their numbers and the coordinates of their centroids. In the VISUM network file, coordinates of the zone centroid and the zone number are compulsory [37]. These attributes were exported directly from the TP+ network file.

4.3.3 Links

Links define roads or railway tracks in the transport network. They are described as "FromNodeNr" or "ToNodeNr" [37]. These two link directions represent two separate objects in the network model although they have the same link number. In addition, each link has a list of permitted and blocked transportation systems. This means that some transportation modes cannot be applied to some links.

Link numbers from the WFRC model were not suitable for this model because the WFRC model covered a larger area (Provo and Ogden urban areas).

4.3.4 Turning Relations and Penalties

A turning relation specifies whether a turning movement is permitted at a node (intersection). Turning time penalties and capacities can be specified for each intersection [37]. The turning relations and the turning penalties were not part of the TP+ network file. Thus, after the links and the nodes were converted to the VISUM network file, the software automatically generated turning relations for all nodes.

The TP+ model could not define the capacity of an intersection and time penalties for its turning movements. Therefore, the WFRC model incorporated these intersection-related impedances into the free flow speeds of the links. This study used the same approach in the VISUM model. The gathering capacity and time penalties for each intersection in the network were beyond the scope of the study.

4.3.5 Connectors

Connectors were defined in the The TP+ network as the links between zones and nodes. They represent the access and egress routes between the zone centroids and nodes (intersections) [37]. Zones were represented as nodes with numbers up to 1400. Connectors were extracted from the TP+ network files using a filter. VISUM connectors are defined as "ZoneNr" or "NodeNr."

4.3.6 User-Defined Attributes

The VISUM network model used other user-defined attributes. Some were link-related data obtained from the WFRC traffic assignments. Some of these link attributes were later used to calibrate the model.

4.4 Diurnal Traffic Periods

The U.S. Department of Transportation recommends dividing transportation modeling into different time periods according to different trip purposes *(3)*. WFRC divides its modeling procedures into these periods:

AM peak period (AM) – 6:00 AM to 9:00 AM
Mid-day period (MD) – 9:00 AM to 3:00 PM
PM peak period (PM) – 3:00 PM to 6:00 PM
Evening period (EV) – 6:00 PM to 6:00 AM

A fifth diurnal period models night reconstruction work. This night period is from 10:00 PM to 6:00 AM. Complete overnight closures took place on I-15 from 600 North to 10600 South throughout the construction period. Four period assignments provided accurate assessment of the traffic congestion and delays experienced during I-15 reconstruction. Road capacities are determined by single lane capacities (number of vehicles/lane/hour), number of lanes, and number of hours in each diurnal period. The single lane capacities were obtained from the WFRC model. These capacities were based on road type and free flow speed.

Diurnal period measurements increase accuracy. If traffic assignments were modeled for daily travel demand, the daily link capacity would be:

Daily Link Capacity = (Cap/Hour/Lane) x (# Lanes) x (24 Hours)

Traffic flow is not the same during all twenty-four hours, but the model considers a twenty-four-hour period. Without diurnal periods a model would not recognize links as congested during the peak hours. The traffic assignment procedure would not recognize any need for traffic rerouting. Therefore, results from this kind of assignment could be very inaccurate.

4.5 Travel Demand

Travel demand has increased significantly in the Salt Lake Valley over the last 20 years. This trend is expected to continue in the future *(4)*. In this study, travel demand for all alternatives is modeled according to improved freeway capacity. The model assumes that only network configuration and travel demand for private trips can be changed. It does not assume that different modes of travel contribute to total travel demand. Because the model has only two variables, it is easy to find correlations between user delays and short-term changes (road closures due to reconstruction) and between user delays and long-term changes (increase in travel demand).

Travel demand data is obtained from the WFRC. Trip tables document the number of trips between each pair of zones (600 x 600 zones). There are separate trip tables for each of the four diurnal periods. The evening trip table from the WFRC is used to extrapolate two trip tables for the 6:00 PM to 6:00 AM period.

Travel demand tables are provided for 1996, 2000, 2005 and 2010. OD tables are extrapolated from travel demand tables for 2003 and 2007. They create a more accurate picture of intermediate travel demand. The OD tables are assigned to different annual network configurations (1996 to 2010). The road networks do not change after 2001 for the DB and NB alternatives. They do not change for TB 2007. Table 4.2 shows the OD matrices assigned to each annual network configuration.

Table 4.2: Assignment of the OD tables to network configurations

OD Table	Updated Networks		
	No-Build	Design-Build	Traditional-Build
1996	1996,1997,1998	1996,1997,1998	1996,1997,1998
2000	1999, 2000,2001	1999, 2000,2001	1999, 2000,2001
2003	2001	2001	2002, 2003
2005	2001	2001	2004, 2005
2007	2001	2001	2006, 2007
2010	2001	2001	2007

4.6 Selection of the MOEs

The VISUM traffic system produces transportation system metrics such as average link speed, travel time, link length, and volume/capacity (V/C) ratio. These metrics are used to calculate MOEs. The following four MOEs compare user delay costs and transportation system performance for DB, TB, and NB.

Vehicle Hours of Delay (VHD) – This is a region-wide traffic system measure. VHD represents the difference between vehicle-hours on a traffic-loaded link and vehicle-hours on a free flow traffic link.

Vehicle Miles of Travel (VMT) - This is also region-wide. It aids in the computation of other user cost outputs such as emission levels and accident numbers. It is computed as a product of link length and traffic volume on the link at a specific time.

Travel Time – This is used to evaluate the impact of different traffic loads during and after I-15 reconstruction periods. Travel time between two points on I-15 is obtained using the route-search option in the VISUM program.

Percentage of the congested links – This represents the percentage of links in the network that have PM peak saturations (V/C ratios) larger than 0.9. A V/C ration of 1.0 means that traffic volume on a link is equal to link capacity. This MOE was computed using the counting and filtering functions in Microsoft Excel.

5. MODEL CALIBRATION

Link traffic volume is used as a calibration measure. Real traffic data are compared with modeled traffic volumes on links to obtain a coefficient of determination, or the strength of the correlation between two sets of data. If coefficient of determination indicates weak correlation between two sets of data, certain parameters are changed and the coefficient is computed again. Model estimation finds the values of the model parameters and increases the likelihood of fitting observed travel data. Model estimation specifies the form of the model and determines the statistical significance of the variables. The model estimation of the traffic-forecasting model used in the study is not a part of this report. The estimation was done by the WFRC. This study used the same coefficients for the traffic assignments.

Usually after model parameters are estimated, the calibration process adjusts parameter values until predicted traffic matches observed travel demand in the region. The model calibration in this study consistsof two parts.

Real traffic data is required to calibrate the model *(5)*. The Average Annual Daily Traffic (AADT) counts must be adjusted for the directions, travel demand periods, and road types used in the analysis. After the volumes are adjusted to a three-hour, a six-hour and a twelve-hour period, they can be compared with modeled volumes for the four diurnal periods.

Adjustment coefficients are needed to compute the average peak-traffic volumes from AADT data. The coefficients are obtained by analyzing data from Automatic Traffic Recorders (ATR) in the Salt Lake Valley *(6)*. The model calibration process also requires adjustments of the coefficients in the VISUM traffic assignment procedures, volume-delay relations, and link impedances.

5.1 Adjustment of the AADTs

The 1996 AADT counts are the only data appropriate for calibration. More recent AADTs cannot be used because the traffic volumes are influenced by reconstruction.

There are approximately 5500 links in the VISUM used in this study. About 1600 of these links provide AADT data. Hourly traffic volumes from 21 ATR locations are gathered to determine average percentages of daily traffic during peak periods in peak directions. These 21 locations provide hourly data for about 35 links. Most of the links are in two-direction locations.

Road classification is an important factor in preparing traffic assignment models. Generally, traffic volumes are assigned to the links based on their capacities and free-flow speeds. The road classifications for the VISUM network and WFRC model are the same.

A diurnal period analysis finds the percentages of AADT on the links during the four different diurnal periods. Hourly traffic volumes from ATR locations are combined to obtain traffic volumes for each of the four periods. The period volumes are then divided by the AADT volumes. Table 5.1 lists the ATR locations examined in this study.

Table 5.1: Automatic traffic recorders in Salt Lake County

Station Number	Road Type	Direction
302	11 Freeway Higher Capacity	N-S
325	34 Minor Arterial Suburban	N-S
332	24 Principal Arterial	N-S
333	24 Principal Arterial	N-S
335	35 Minor Arterial Suburban	E-W
340	11 Freeway Higher Capacity	E-W
341	11 Freeway Higher Capacity	E-W
344	11 Freeway Higher Capacity	N-S
345	19 Freeway On ramp	E-W
346	19 Freeway Off ramp	E-W
347	11 Freeway Higher Capacity	N-S
351	11 Freeway Higher Capacity	E-W
353	11 Freeway Higher Capacity	N-S
354	24 Principal Arterial	E-W
355	36 Minor Arterial Suburban	E-W
356	11 Freeway Higher Capacity	E-W
406	27 Principal Arterial	N-S
407	40 Rural Highway	N-S
408	35 Minor Arterial Suburban	N-S
409	35 Minor Arterial Suburban	E-W
501	11 Freeway Higher Capacity	N-S

5.1.1 Selection of the Representative Month

To adjust AADT data, a representative month for gathering ATR data must be chosen. This month should be one in which ADT (Average Daily Traffic) is closest to AADT for most ATRs. Different locations had different months when ADTs were closest to the AADT. Therefore, a simple statistical analysis was done to determine the representative month. Monthly ADT was compared with AADT in all of the twenty-one ATR locations. An ADT was considered close to AADT if it was within a range of ± 3 percent. Its frequency of being within three percent of AADT was the largest for twenty-one ATR locations. May was selected as the representative month. Next, traffic volumes from 21 ATR locations were gathered from UDOT. ATR site data sheets contained hourly traffic volumes for 31days of the month. The sheets also provided average daily traffic, traffic totals, and other statistics. Figure 5.1 shows layout of the ATR locations in the Salt Lake County.

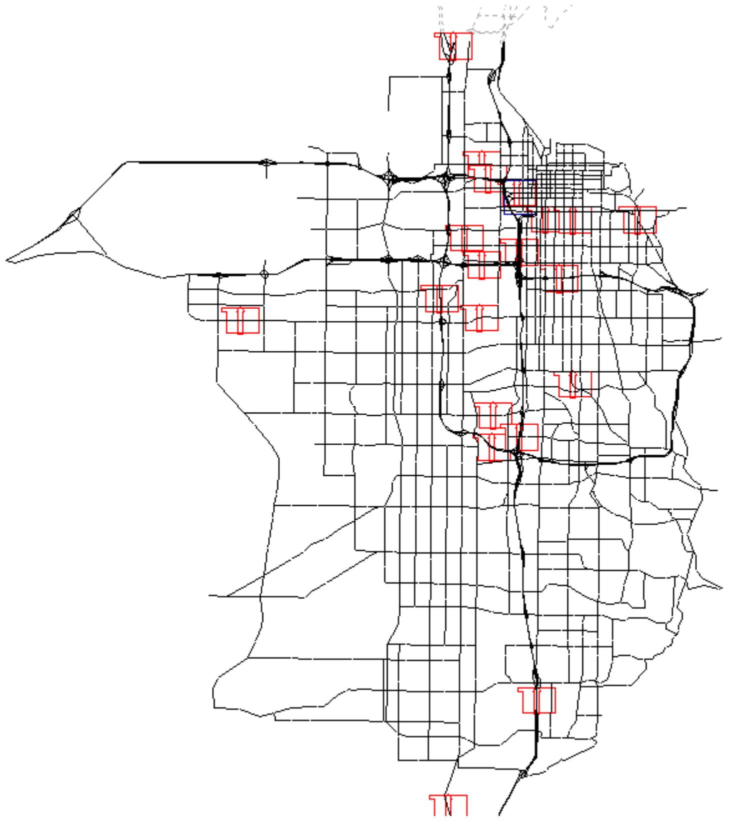


Figure 5.1: Layout of the ATRs in the Salt Lake Valley

5.1.2 Road Classification

Generally, the traffic volumes are assigned on links based on their capacities and free-flow speeds. Freeways and highways attract more traffic than arterial streets because their capacities and free flow speeds are designed to handle higher traffic volumes. Table 5.2 provides the road classification system used by the WFRC model. VISUM used the same classification system in this study.

5.1.3 Diurnal-Period Analysis

Hourly traffic volumes from ATR locations were combined to obtain the traffic volumes for the four periods. These volumes were then divided by AADT volumes to find the contributions of the four periods to daily traffic volumes (AADT). It was unclear whether their contributions were consistent among the different road types.

Table 5.3 shows statistical analysis results for 21 ATR locations by diurnal period. Coefficients represent the percentage of total daily traffic occurring during different diurnal periods on different road classes. The analysis determined that there is significant difference in the percentage of traffic during a certain time of day on different road types.

The average coefficients from Table 5.3 were multiplied by AADTs. These values were then compared with the periodical traffic volumes from the ATRs.

Table 5.2: WFRC road classification

Nr	Capacity Veh/H	V_0 km/h	Vmax km/h	Name	Capacity V/L/Hour	# Lanes
1	70000	32	56	Centroid		
11	8800	105	129	Freeway - Higher capacity	2200	4
12	5700	105	129	Freeway - Lower capacity	1900	3
13	3460	80	105	Freeway – Collector distributor	1730	2
14	2200	105	129	Freeway - HOV lanes	2200	1
15	1900	121	145	Freeway - Rural/High speed	1900	1
16	1900	64	88	Freeway - Off ramp	1900	1
17	1900	48	72	Freeway - Off ramp loop	1900	1
18	1600	56	80	Freeway - On ramp	1600	1
19	1600	40	64	Freeway - On ramp loop	1600	1
20	3460	80	105	Multilane Hwy	1730	2
21	2280	37	61	Principal arterial - Urban	760	3
22	1340	35	60	Principal arterial - Urban	670	2
23	600	34	58	Principal arterial - Urban	600	1
24	2490	55	79	Principal arterial - Suburban	830	3
25	1460	53	77	Principal arterial - Suburban	730	2
26	670	50	74	Principal arterial - Suburban	670	1
27	2700	66	90	Principal arterial - Suburban fringe	900	3
28	1600	64	88	Principal arterial - Suburban fringe	800	2
29	730	61	85	Principal arterial - Suburban fringe	730	1
31	2100	32	56	Minor arterial - Urban	700	3
32	1200	31	55	Minor arterial - Urban	600	2
33	530	29	53	Minor arterial - Urban	530	1
34	2280	48	72	Minor arterial - Suburban	760	3
35	1340	47	71	Minor arterial - Suburban	670	2
36	600	43	68	Minor arterial - Suburban	600	1
37	2490	60	84	Minor arterial - Suburban fringe	830	3
38	1460	58	82	Minor arterial - Suburban fringe	730	2
39	670	55	79	Minor arterial - Suburban fringe	670	1
40	900	93	117	Rural Hwy	900	1
41	2100	29	53	Collector street - Urban	700	3
42	1200	29	53	Collector street - Urban	600	2
43	530	26	50	Collector street - Urban	530	1
44	2100	45	69	Collector street - Suburban	700	3
45	1200	43	68	Collector street - Suburban	600	2
46	530	40	64	Collector street - Suburban	530	1
47	2280	56	80	Collector street - Suburban fringe	760	3
48	1340	55	79	Collector street - Suburban fringe	670	2
49	600	51	76	Collector street - Suburban fringe	600	1
51	700	56	80	Fast mountain road	700	1
52	530	40	64	Slow mountain road	530	1

Table 5.3: Adjustment coefficients for AADT volumes

Road Type	AM (6-9 AM)	MD (9 -3 PM)	PM (3-6 PM)	EV (6PM – 6AM)
Freeway	0.123	0.332	0.212	0.333
Principal Arterial	0.098	0.362	0.212	0.328
Minor Arterial	0.081	0.340	0.218	0.362
Other	0.113	0.311	0.221	0.355
Average	0.106	0.336	0.217	0.341

Table 5.4 shows coefficients of determination (R^2) for adjusted AADTs and periodical volumes based on hourly ATR volumes.

Table 5.4: R^2 for adjusted AADT and ATR volumes

Diurnal period	R^2
AM Peak	0.93
Midday	0.99
PM Peak	0.98
Evening	0.99

5.1.4 Peak-Direction Conversion

Because ATR data was available for both directions on links, directional split factors were included in the percentages of ATR volumes in the AADTs. Figure 5.2 shows the directional split percentages of traffic from an ATR located on I-15. Figure 5.3 shows the typical daily traffic profile from the same location.

5.2 Adjustment of the VISUM Assignment Coefficients

5.2.1 Type of the Assignment

VISUM provides four types of traffic assignment procedures: incremental assignment, equilibrium assignment, learning method and TRIBUT, a bicriterion assignment that equally considers travel time and cost. Equilibrium and the learning method were used for the traffic assignments in this study. The equilibrium procedure distributes demand according to Wardrop's first principle: "Every individual road user chooses his route in such a way that this trip takes the same time on all alternative routes and that switching routes would only increase personal journey time." [37. 2-28].

Equilibrium is reached by multisuccessive iteration based on incremental assignment. In the inner iteration step, two routes of a relation are brought into a state of equilibrium by shifting vehicles. The outer iteration step checks whether new routes with lower impedance can be found from the current network state.

Learning method simulates the "learning process" on the road network. The total traffic flow is assigned to the shortest routes found for each iteration step. Only the network impedances in the free network are taken into account in the first iteration step. Impedance is calculated by using the impedances from current volume. Every iteration step n is based on the impedances calculated at n-1 [37]. The procedure ends when the estimated times underlying the route choice and the actual journey times coincide to a sufficient degree. There is a high probability that this stable state of the traffic network corresponds to the route choice of drivers [37].

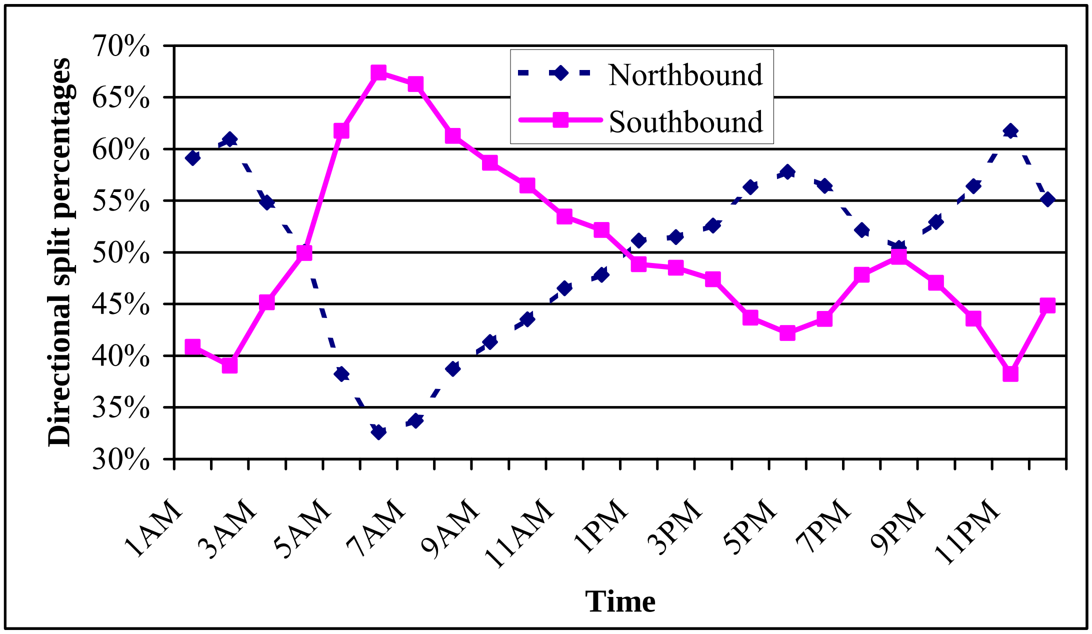


Figure 5.2: Directional split of the diurnal traffic on an I-15 segment

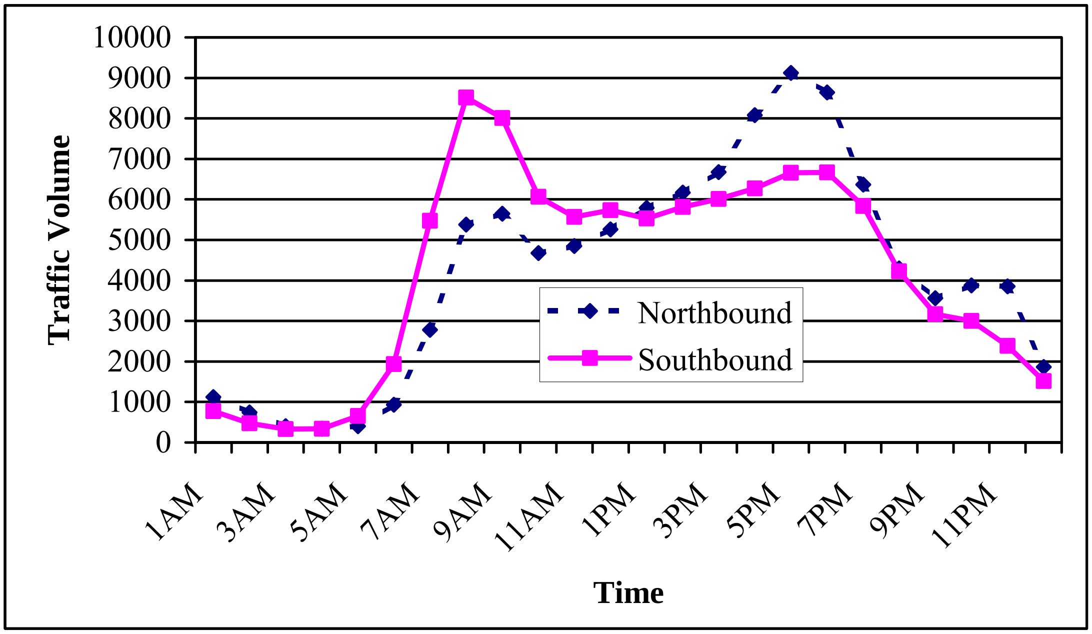


Figure 5.3: Daily traffic on an I-15 segment

5.2.2 Volume-Delay Relationships

Volume-delay relationship is another important factor in traffic assignment. As traffic volumes increase, travel speed decreases due to increased congestion. The Bureau of Public Roads (BPR) function is most commonly used to relate changes in travel speed to increases in travel volume. The BPR function is:

$$T_f = T_0 \cdot \left(1 + \alpha \cdot \left[\frac{V}{C}\right]^{\beta}\right)$$

Where:
T_f = final link travel time
T_0 = original (free-flow) link travel time
α = coefficient (often set at 0.15)
V = assigned traffic volume
C = the link capacity
β = exponent (often set at 4.0)
However, the BPR function does not represent accurate traffic volumes in the equilibrium traffic assignments. On the links with low volume/capacity ratios, additional traffic assigned to the link has a very little effect on the travel speed. For volume/capacity ratios greater than 1.0 the BPR function causes the assignment to iterate to closure more slowly [37].

The VISUM model provides several options for finding the relationship between volume and delay. In addition to the common BPR functions it offers two modified BPR functions: saturated and unsaturated *(7)*. The BPR function is also used in WFRC's TP+ model. The traffic volumes assigned by WFRC can be used to calibrate traffic assignment results for the model. The TP+ model uses two types of common BPR functions for two general road classes. The coefficients for these two BPR functions are:

Freeway BPR: α=0.88, β=6.50
All other roads BPR: α=0.15, β=4.00

Multilane highways were also introduced based on the Highway Capacity Manual's table for BPR parameters *(8)*. The coefficients for this BPR function are:

Multilane Highways: α=0.71, β=2.10
Table 5.5 shows parameters of the common BPR function modified through Highway Capacity Manual procedures.

Table 5.5: Modified BPR parameters

Coefficient	Freeways			Multilane		
	70 mph	60 mph	50 mph	70 mph	60 mph	50 mph
Alpha	0.88	0.83	0.56	1.00	0.83	0.71
Beta	9.80	5.50	3.60	5.40	2.70	2.10

5.2.3 Impedance

Traffic assignments depend on travel impedances. In the simplest case, impedance is the same as travel time because users select their routes based on travel time between origin and destination. A more refined procedure incorporates time, distance, or any type of user cost into impedance calculation *(7)*.

Total link impedance can generally be expressed as:

$$Cost_{total} = a \cdot Time_{Link} + b \cdot Length_{Link} + c \cdot Cost_{Link}$$

Where:
a, b, and c are coefficients that add up to 1.
$Cost_{total}$ = total link impedance
$Time_{Link}$ = travel cost due to time required to traverse the link (or time itself)
$Length_{Link}$ = travel cost due to link distance (or distance itself)
$Cost_{Link}$ = travel cost due to other impedances (delay, toll, etc.)

The impedance equation used in this study was similar to that used in the WFRC model. The WFRC equation considers travel time and distance. Model calibration required adjustment of coefficients a and b to get modeled link volumes as close as possible to counted traffic volumes. The coefficients used by WFRC (a=0.75, b=0.25) were not proven best for the VISUM model.

Table 5.6 shows a combination of the different assignment procedures, volume-delay functions, and travel impedances used to calibrate the model. There is one traffic assignment for each combination of options in the table. After each of these traffic assignments is modeled, link volumes are compared with real traffic data (adjusted AADT volumes). The best matches for modeled volumes and adjusted AADT data are obtained from the equilibrium assignment procedure, the modified WFRC volume-delay function, and the link impedance (link travel time contributed 95%). These parameters are used to model all traffic assignment procedures.

All coefficients of determination had very close values. The modeled and observed results could only match more closely if the methodology were changed. The coefficient of determination indicates that the parameters for traffic assignments in this study are slightly more successful than those in the WFRC model. The WFRC coefficient of determination is about 0.79. Table 5.6 shows the coefficients of determination obtained in the study.

Table 5.6: Coefficients of determination for different calibration options

<table>
<tr><td rowspan="4" colspan="2">R^2
(Coefficient of Determination)</td><td colspan="6">Assignments</td></tr>
<tr><td colspan="3">Equilibrium Assignment</td><td colspan="3">Learning Assignment</td></tr>
<tr><td colspan="3">Impedance</td><td colspan="3">Impedance</td></tr>
<tr><td>T=0.9
D=0.1</td><td>T=0.95
D=0.05</td><td>T=1.0
D=0</td><td>T=0.9
D=0.1</td><td>T=0.95
D=0.05</td><td>T=1.0
D=0</td></tr>
<tr><td rowspan="2">Vol-delay Function</td><td>WFRC</td><td>0.7226</td><td>0.7968</td><td>0.7638</td><td>0.7331</td><td>0.7970</td><td>0.7602</td></tr>
<tr><td>Modified</td><td>0.7436</td><td>0.8017</td><td>0.7608</td><td>0.7437</td><td>0.8012</td><td>0.7607</td></tr>
</table>

5.3 Calibration Results

Figure 5.4 shows the coefficient of determination between VISUM and AADT average daily traffic volumes. 0.8 does not satisfy the federal recommendation for region-wide traffic forecasting. Figure 5.5 shows the coefficient of determination between WFRC and VISUM. The results indicate strong correlation between these two models. The best fit of real traffic data is obtained for the equilibrium assignment, the modified WFRC volume-delay function and traffic impedance that formed 95 percent based on travel time and 5 percent based on the distance between origin and destination. These parameters are used in further modeling for all traffic assignment procedures.

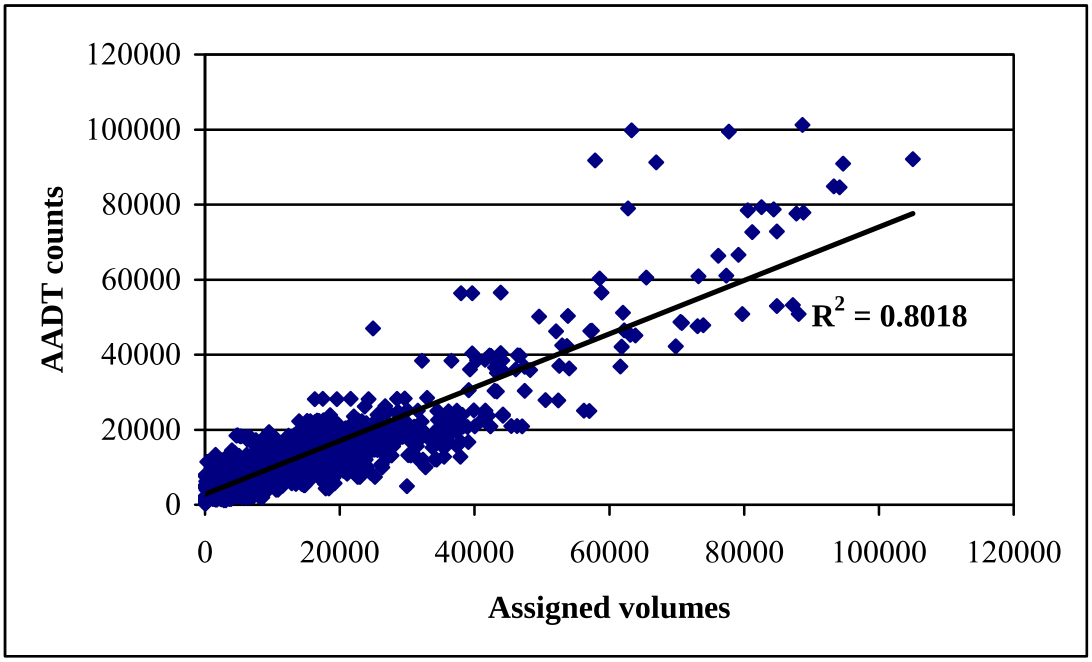


Figure 5.4: Assigned versus observed (AADT) daily volumes

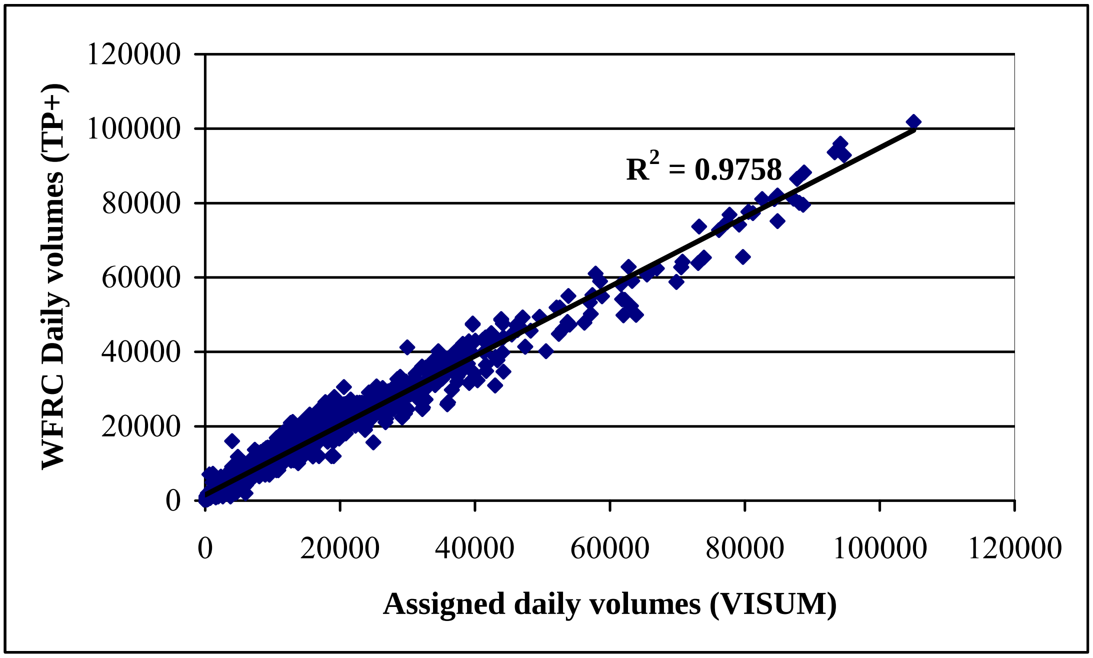


Figure 5.5: Assigned versus WFRC daily volumes

6. TRAFFIC ASSIGNMENTS

Traffic assignments are performed for all network configurations. The assignments reflect road openings and closures for each reconstruction alternative. A separate traffic assignment is run after each major opening or closure of the interchange or road section. Critical time represents the minimal time period that a road network configuration affects traffic. A month is needed to measure the network configurations for the DB alternative. Critical time is assumed to be three times longer for the TB alternative than for the DB alternative. Figure 6.1 shows closure activities on the I-15 interchange.

6.1 Configuration of the Annual Road Networks

The WFRC provides the initial link network prior to I-15 reconstruction. The network is modified for both Transportation Improvement Program (TIP) capacity improvements and capacity improvements that minimize traffic rerouting from I-15. These network updates are performed from 1996 to 2001. The TIP capacity improvements incorporated into the modeling are common for all alternatives. They involve only major improvements of the road network prior to 2001. Potential road improvements after 2001 are not considered.

Capacity improvements on roads in Table 6.1 could have an important impact on network performance in the traffic assignment procedure. Table 6.1 shows the year in which these network improvements became relevant for the traffic assignments. Some of the roads were (re)constructed over several years. However, they were only important to this study when they became fully functional.

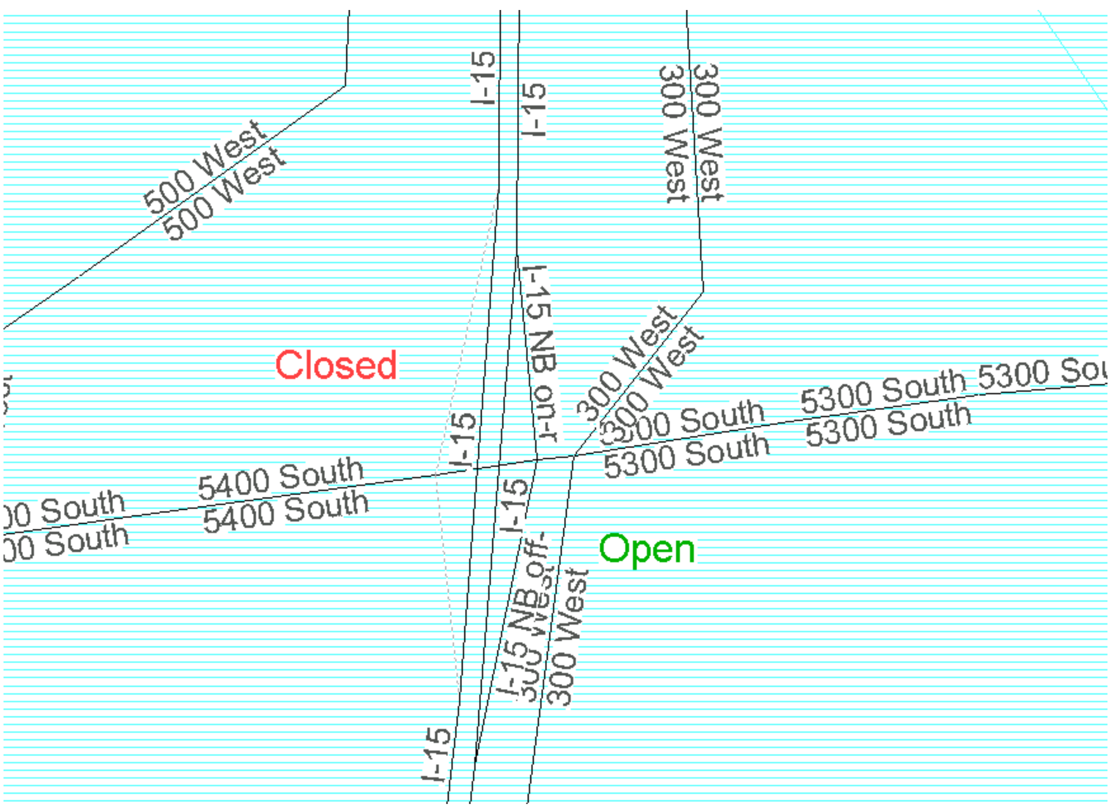


Figure 6.1: An example of the closed NB ramps on 5300 South

Table 6.1: TIP road improvements in the network

Street name	From	To	Year
Bangerter Hwy	9800 S	13800 S	1998
10200 S	3200 W	Bangerter Hwy	1998
700 W	9000 S	10600 S	1999
4000 W	7000 S	7800 S	1999
3600 W	11400 S	12600 S	1999
4800 W	6200 S	9000 S	1999
9000 S	Old Bingham Hwy	4800 W	1999
4800 W	Parkway Blvd	3100 S	2000
Parkway Blvd	Bangerter Hwy	5600 W	2000
7000 S	5600 S	4800 S	2000
7000 S	700 W	1300 W	2000
11400 S	2700 W	Bangerter Hwy	2000

6.1.1 Mitigation Measures for the I-15 Reconstruction

The main north-south principal arterials used to deter I-15 traffic are improved. The 1997 network configuration includes improvements to Redwood Road, Main Street, State Street, and 700 East. I-215 adds a lane and is re-striped during reconstruction to ensure that traffic functions successfully. All altered roads are returned to their previous conditions after the completion of I-15 reconstruction.

6.2 Closure Schedules for DB and TB Alternatives

This section describes both the actual I-15 closures under the DB reconstruction *(9)* and the hypothetical closures for the TB alternative. The TB closures are developed based on several interviews with UDOT employees. These employees are involved in the safety, contracting, and construction aspects of the I-15 project.

The total duration of the TB project is 11 years. The first two years are spent designing the interchange(s) and/or freeway segment(s) to be built during the initial phase of reconstruction. Construction then begins and all tasks for the next interchanges/segments are designed.

UDOT experts recognize the following factors as the most important for work and road closures with DB and TB.

1. Two lanes per direction of the I-15 mainline should remain open throughout the reconstruction period. The freeway can close completely at night. Only two interchanges with two freeway sections can be closed at the same time.
2. Two of the 600 North, 400 South, 500 South/600 South, and 900 South accesses to the downtown Salt Lake area should be open at all times during the project (9).
3. In order to be fair to the local businesses, UDOT states that as long as the northbound/southbound ramps at one interchange are closed, the same ramps at any consecutive interchange should remain open.
4. Single interchange closure greatly impacts reconstruction time for any alternative. About one year is needed to finish one interchange in the DB project. The entire arterial street and its ramps are closed for six months. The freeway-to-freeway junctions (I-215/I-15 or I-80/SR201) or pairs of associated interchanges (500 South and 600 South) take up to two years to complete. With the TB method, potential construction time for a single interchange is estimated to last at least two years for a single interchange and up to three years for a junction or pair of interchanges.

DB and TB road closures are different. Under DB, the entire corridor had reduced capacity with only two lanes open. Numerous ramps on all interchanges were closed at different times. TB reduced capacity to two lanes only in the vicinity of two interchanges closed at the same time. This caused two bottlenecks on the corridor and restricted access to and from the rest of the road network for a longer time period.

DB and TB differ mainly in project completion length. A UDOT employee said that the difference between construction times for DB and TB results because DB does not have to wait for a design to be completed. Also, on the I-15 project, DB allowed more flexibility and ingenuity for the contractor than the traditional methods [41].

DB was a time-driven project that deployed intense work force to finish the project in a short time. In order to satisfy due dates for the project completion, two ten-hour work shifts took place per day. At night materials were loaded and unloaded. This saved truck drivers time waiting on congested roads [42]. The overall efficiency of almost any construction task in the DB project was about 2.5 to 3 times better than TB. Time periods for tasks during DB reconstruction were multiplied by three to find their completion time with TB.

The critical time unit for DB construction was one month. Therefore, three months was the critical time unit for TB. Table 6.3 outlines TB facility closures by three month periods in terms of seasons. The schedule was based on the latest Wasatch Constructors' schedule of work activities. The schedule of closures for the TB alternative is developed based on the assumptions made in this study. A traffic assignment is made for each closure profile of the network and for each diurnal period. After traffic assignments are completed for all daily periods, the next road closure is taken into consideration and the next traffic assignment is performed. Detailed graphical presentations of the schedules are provided in the Appendix E.

6.3 Computation of the MOEs

After each VISUM traffic assignment was completed, the outputs were exported into an Excel spreadsheet. These outputs were used to compute the MOEs defined in Chapter 4. The most useful outputs were:

- Assigned traffic volume on the link
- Length of the link
- Vehicle-hours on traffic-loaded link
- Vehicle-hours with the free flow travel time on the link
- Link saturation (V/C ratio)

These five basic link attributes were used to compute all major MOEs.

Figure 6.2 shows a layout of the VISUM traffic assignment. The network links were loaded with the AM traffic. The width of the shaded area represents the intensity of the traffic volume. The numbers in the background represent the numbers of the areas introduced by the WFRC. Figure 6.3 shows the congested links on one of network configuration during the PM peak.

Table 6.2: Design-Build schedule of important facility closures

Facility	Type & Duration of closure	Close	Open	Close	Open
600 N	Off & On Ramps - 17 months	May-97	-	-	Oct-98
600 N	Arterial @ 300 & 900 W - 17 months	May-97	-	-	Oct-98
600 N	400 W @ 500 & 700 N - 16 months	Jun-97	-	-	Oct-98
I-15/80	I-80E to I-15N - 38 months	Jul-97	-	-	Aug-00
I-15/215	Strategic I-215W to 15N - 47 months	Jul-97	-	-	May-01
1300 S	SB On - 37 months	Jul-97	-	-	Jul-00
7200 S	SB On - 16 months	Jul-97	-	-	Nov-98
500 S	NB On to I-80W - 43 months	Jul-97	-	-	Jan-01
7200 S	SB Off - 15 months	Aug-97	-	-	Nov-98
3300 S	NB On & Off – 47 months	Aug-97	-	-	Jun-01
4500 S	SB On & Off - 16 months	Aug-97	-	-	Dec-98
7200 S	SB Off from I-215 - 15 months	Aug-97	-	-	Nov-98
7200 S	NB On - 17 months	Aug-97	-	-	Jan-99
I-15/215	I-15N to I-215E - 14 months	Sep-97	-	-	Nov-98
I-15/80	I-80W to 15S/NC - 25 months	Sep-97	-	-	Oct-99
2100 S	All Ramps - 24 months	Sep-97	-	-	Sep-99
1300 S	NB On - 34 months	Sep-97	-	-	Jul-00
10600 S	SB On - 12 months	Oct-97	-	-	Oct-98
400 S	Arterial - 43 months	Nov-97	Sep-99	-	May-01
10600 S	SB Off - 13 months	Nov-97	-	-	Dec-98
1300 S	SB Off - 33 months	Jan-98	-	-	Oct-00
I-15/80	I-80E to I-15S – 37 months	Apr-98	-	-	Apr-01
I-15/80	I-15N to I-80W - 32	Apr-98	-	-	Nov-00
7200 S	NB Off - 15 months	Jun-98	-	-	Sep-99
I-15/80	I-15S to I-80W - 35 months	Aug-98	-	-	Jun-01
10600 S	NB On - 15 months	Sep-98	-	-	Dec-99
10600 S	NB Off - 3 months	Sep-98	-	-	Dec-98
600 S	Arterial - 25 months	Sep-98	Oct-99	-	Oct-00
9000 S	SB On - 24 months	Oct-98	-	-	Oct-00
9000 S	SB Off - 22 months	Dec-98	-	-	Oct-00
5300 S	SB Off - 19 months	Dec-98	-	-	Jul-00
5300 S	SB On - 19 months	Dec-98	-	-	Jul-00
500 S	500S to I-15N - Forever	Jan-99	-	-	Jan-99
9000 S	NB On - 21 months	Jan-99	Sep-99	Mar-00	Oct-00
500 S	SB On to I-15S - 26 months	Feb-99	-	-	Apr-01
4500 S	NB On & Off - 3 months	Aug-99	-	-	Nov-99
3300 S	SB On & Off - 22 months	Aug-99	Jul-00	Jan-02	Jun-01
9000 S	NB Off - 13 months	Sep-99	-	-	Oct-00
I-15/215	I-215E to I-15N - 10 months	Sep-99	-	-	Jul-00
2100 S	NB On & Off – 14 months	Sep-99	-	-	Nov-00
900 S	NB Off - 19 months	Oct-99	-	-	May-01
900 S	SB On - 19 months	Oct-99	-	-	May-01
5300 S	NB Off - 8 months	Nov-99	-	-	Jul-00
5300 S	NB On - 8 months	Nov-99	-	-	Jul-00
1300 S	NB Off - 11 months	Jan-00	-	-	Dec-00
9000 S	Arterial - 7 months	Mar-00	-	-	Oct-00
2100 S	Arterial @ 600W to 1050W - 10 months	Jul-00	-	-	May-01
4500 S	Arterial & All ramps - 6 months	Jul-00	-	-	Jan-01
2100 S	SB On & Off - 6 months	Nov-00	-	-	May-01

Table 6.3: Traditional-Build schedule of important facility closures

Facility	Type & duration of closure	Close	Open	Close	Open
600 N	Arterial – 12 months	Fall-98	-	-	Fall-99
600 N	NB On&Off – 9 months	Spring-97	Winter-97	Fall-98	Fall-99
600 N	SB On&Off – 9 months	Winter-97	-	-	Fall-99
I-15	600 N to I-80 – 24 months	Fall-97	-	-	Fall-99
900 S	SB - 12 months	Spring-97	-	-	Spring-98
900 S	NB - 12 months	Spring-98	-	-	Spring-99
I-15	900 S to 2100 S – 24 months	Spring-97	-	-	Spring-99
3300 S	Arterial – 12 months	Spring-99	-	-	Spring-00
3300 S	NB On&Off – 9 months	Spring-98	Winter-98	Spring-99	Spring-00
3300 S	SB On&Off – 9 months	Fall-98	-	-	Spring-00
I-15	2100 S to 33 S - 24 months	Spring-98	-	-	Spring-00
10600 S	Arterial – 12 months	Spring-99	-	-	Spring-00
10600 S	NB On&Off – 9 months	Spring-98	Winter-98	Spring-99	Spring-00
10600 S	SB On&Off – 9 months	Fall-98	-	-	Spring-00
I-15	9000 S to 106 S - 24 months	Spring-98	-	-	Spring-00
5300 S	Arterial – 12 months	Spring-00	-	-	Spring-01
5300 S	NB On&Off – 9 months	Spring-99	Winter-99	Spring-00	Spring-01
5300 S	SB On&Off – 9 months	Fall-99	-	-	Spring-01
I-15	4500 S to 53 S – 24 months	Spring-99	-	-	Spring-01
7200 S	Arterial – 12 months	Spring-00	-	-	Spring-01
7200 S	NB On&Off – 9 months	Spring-99	Winter-99	Spring-00	Spring-01
7200 S	SB On&Off – 9 months	Fall-99	-	-	Spring-01
I-15	I-15/I-215 to 72 S – 24 months	Spring-99	-	-	Spring-01
2100 S	Arterial – 18 months	Fall-01	-	-	Spring-03
2100 S	NB On&Off – 18 months	Spring-00	-	-	Spring-03
2100 S	SB On&Off – 18 months	Fall-01	-	-	Spring-03
I-15	2100 S to I-80 S – 36 months	Spring-00	-	-	Spring-03
I-15/80	NB On&Off - 12 months	Spring-01	-	-	Spring-02
I-15/80	SB On&Off - 12 months	Spring-00	-	-	Spring-01
500 S	Arterial - 12 months	Fall-02	-	-	Fall-03
500 S	NB On&Off – 9 months	Spring-02	-	-	Fall-03
500 S	SB On&Off – 9 months	Spring-02	-	-	Fall-03
600 S	Arterial - 12 months	Fall-02	-	-	Fall-03
600 S	NB On&Off – 9 months	Spring-02	-	-	Fall-03
600 S	SB On&Off – 9 months	Spring-02	-	-	Fall-03
I-15/215	NB On&Off - 12 months	Spring-03	-	-	Spring-04
I-15/215	SB On&Off - 12 months	Spring-04	-	-	Spring-05
I-15	5300 S to I-15/215 - 24 months	Spring-03	-	-	Spring-05
4500 S	Arterial – 12 months	Spring-05	-	-	Spring-06
4500 S	NB On&Off – 9 months	Spring-04	Winter-04	Spring-05	Spring-06
4500 S	SB On&Off – 9 months	Winter-04	-	-	Spring-06
I-15	3300 S to 45 S – 24 months	Spring-04	-	-	Spring-06
9000 S	Arterial – 12 months	Spring-05	-	-	Spring-06
9000 S	NB On&Off – 9 months	Spring-04	Winter-04	Spring-05	Spring-06
9000 S	SB On&Off – 9 months	Winter-04	-	-	Spring-06
I-15	7200 S to 90 S – 24 months	Spring-04	-	-	Spring-06
400 S	Arterial - 12 months	Spring-06	-	-	Spring-07
400 S	NB On&Off - 9 months	Spring-05	Winter-05	Spring-06	Spring-07
400 S	SB On&Off – 9 months	Winter-05	-	-	Spring-07

400 S	I-80/I-15 to 900 S – 24 months	Spring-05	-	-	Spring-07
1300 S	Arterial – 12 months	Spring-06	-	-	Spring-07
1300 S	NB On&Off – 9 months	Spring-05	Winter-05	Spring-06	Spring-07
1300 S	SB On&Off – 9 months	Winter-05	-	-	Spring-07

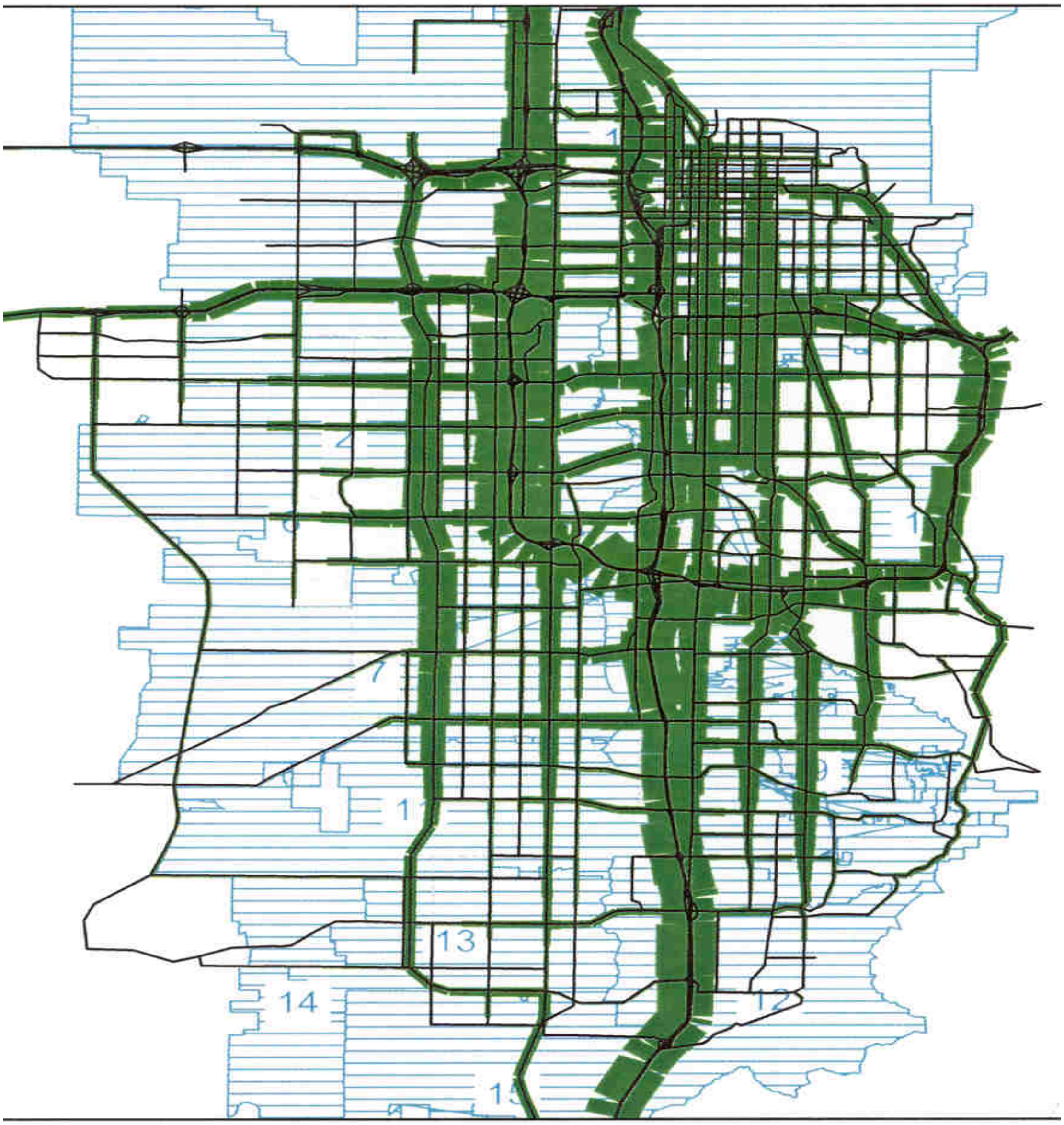


Figure 6.2: A layout of the VISUM traffic assignment

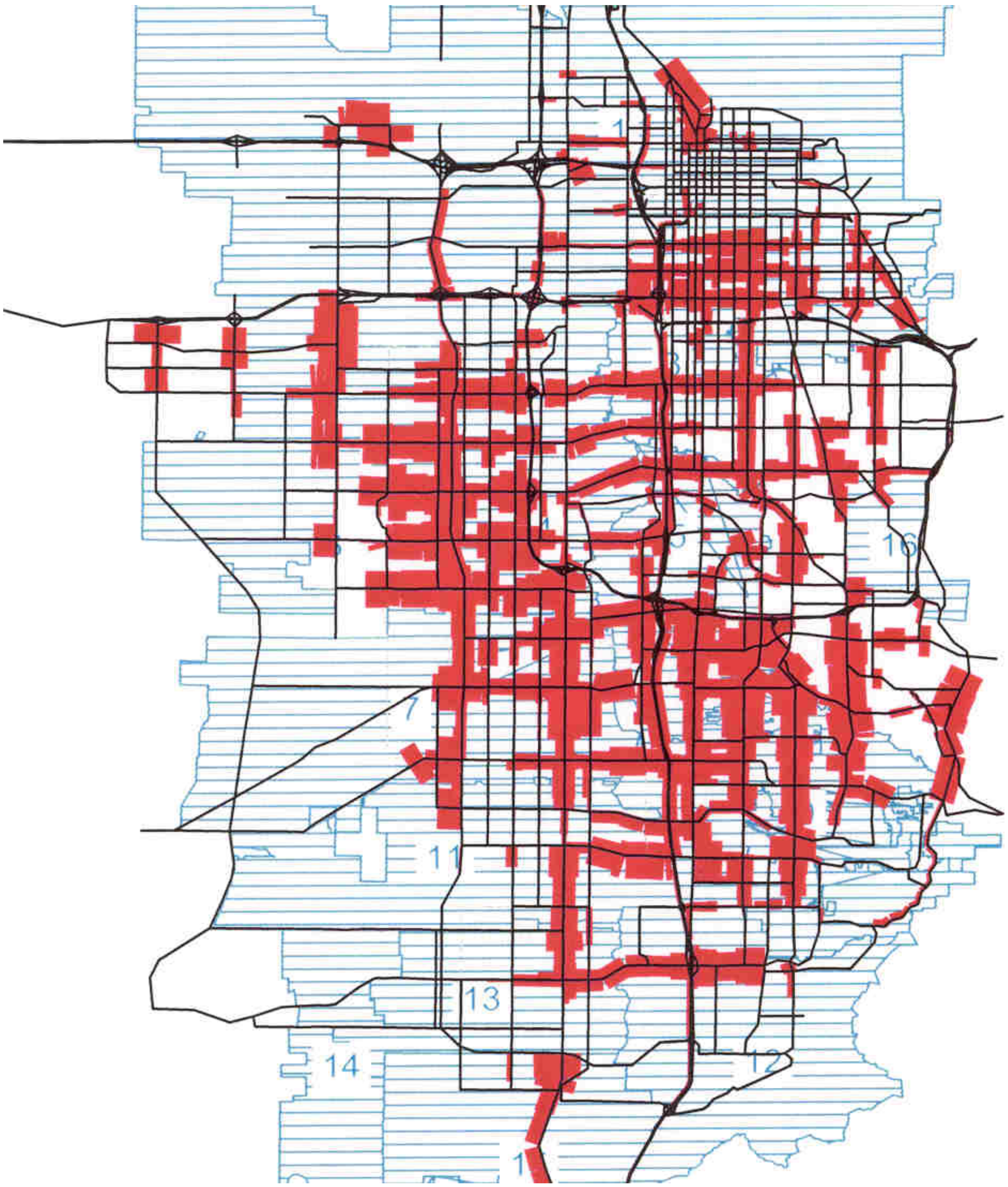


Figure 6.3: A layout of the congested links for a PM peak

A traffic assignment was executed for each closure profile of the network and for each diurnal period. After the traffic assignments were completed for all daily periods, the next road closure was considered and the next traffic assignment was performed.

After VMT and VHD are computed for all diurnal periods, daily totals are obtained by taking a sum of all five diurnal periods. This step is not necessary for MOEs computed by PM peaks. Each daily result for VMT or VHD represents 30 to 90 days of a network-specific profile caused by road closures. Some of the network configurations are valid for several months. In order to obtain annual totals for

VMT or VHD, it is necessary to multiply the daily VMT or VHD by the number of days that the network profiles are valid.

In total, it was necessary to execute 39 traffic assignment procedures to model traffic closures over a four-year reconstruction period for DB. The TB reconstruction required executing 28 traffic assignment procedures for a nine-year reconstruction period. Traffic assignments were also executed for NB. Because each representative day in the model had to be divided into five diurnal periods, the total number of traffic assignments simulated totaled at nearly 370 traffic assignments.

7. RESULTS

7.1 Model Validation

After traffic assignments are finished, results must be checked for validity. The model calibration was conducted by comparing modeled VISUM volumes with field traffic data and results from the WFRC traffic-forecasting model. Double-check of the modeled results served as both the calibration and validation procedure. The validation was not detailed due to the lack of available traffic counts for the 2000 model. The counts are available in the UDOT document “Traffic on Utah’s Highways.” Comparing them with data from modeled link volumes would require manual input into the VISUM network file.

Therefore, for model validation purposes two general characteristics of the transportation systems are compared with the modeled values. These two characteristics are region-wide VMT and travel time on the I-15 corridor.

7.1.1 VMT Validation of the Model

Table 7.1 compares VMT for the model projections and VMT data collected from UDOT. The official UDOT Website offers VMT by functional class of road in each county. Coefficient of determination was not very high in this case. However, this does not necessarily indicate the model’s inability to predict proper VMT results.

Two factors influenced the model’s ability to correctly predict VMT. First, UDOT data includes the VMT data from urban/rural local roads. These were not part of the road network used in this study. Therefore, one would always expect to find differences in the VMT unless the road networks on which data were collected/modeled were identical.

Second, the UDOT VMT data clearly shows that VMT increases over the years. This indicates that as the travel demand increases, more people take more trips and VMT increases.

Table 7.1 shows that while observed VMT gradually increases, modeled VMT remains almost constant between 1996 and 2001. This happens because the model does not have exact input for each year’s travel demand. The shift from the lower travel demand level in 1996 to the higher one in 2000 is not visible because of small differences in travel demand. UDOT and modeled VMT are still roughly close. This indicates that the model used in this study did not produce results unexpected from the observed data.

Table 7.1: The model and UDOT vehicle miles of travel (millions)

	1996	1997	1998	1999	2000	2001
UDOT	6784.92	6955.40	7064.46	7197.96	7314.91	7714.46
Model	6847.75	6724.60	6711.18	6974.22	6977.39	6976.44

7.1.2 Travel Time Validation of the Model

As part of the "HOV Lane Evaluation Study" *(10)* the UTL conducted a travel time survey to compare the travel times between both high-occupancy vehicle (HOV) and general-purpose (GP) lanes on I-15. The travel times were measured for AM peak, PM peak, and off-peak traffic conditions from 400 South to 10600 South. The travel times for GP lanes are used to validate the study model. The average travel time is 19.5 minutes. The model measures an average travel time of 18 minutes for the DB alternative in 2002 for the same distance. This comparison validates the model's capability to estimate travel times.

7.2 User Delays

The user delays in the study must be converted into monetary values in order to be included in the cost-benefit analysis of the reconstruction. However, an assignment of monetary values to each alternative's VHD was beyond of the scope of this study. Figure 7.1 shows the annual vehicle hours of delay in millions.

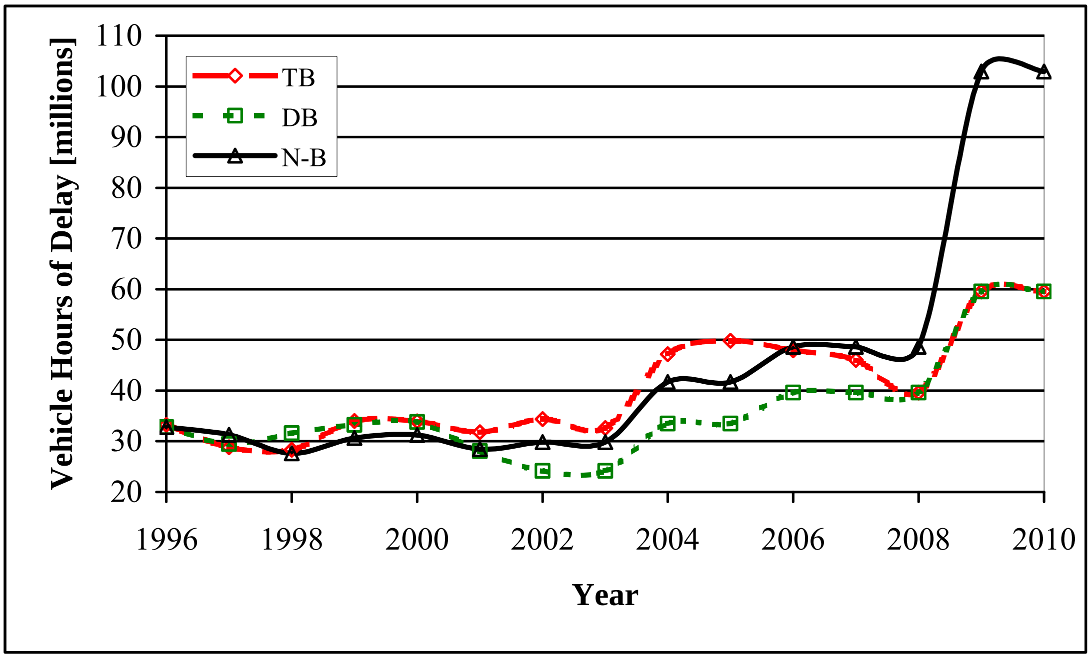


Figure 7.1: Modeled annual VHD data

7.2.1 Annual User Delays

With NB, user delays result only from increased travel demand. The impact of the increased travel demand is apparent in 2009. Figure 7.2 shows a large increase in user delays for the NB alternative. These numbers indicate that new travel demand causes significant delays on the unimproved road network.

Annual user delay alternative increased significantly in 2004 and again in 2009. The VHD for NB is higher from 1996 to 1997 than for DB or TB. However, from 1998 to 2001 this alternative has the lowest user delays among the three reconstruction scenarios.

Annual user delays for the DB alternative decreased in the first year of reconstruction. They then increased until they reached their maximum in 2000. At this point they decreased. In 2002 the user delays associated with DB are the lowest compared to TB and NB. They remain the lowest user delays until 2008. From 2008 until the end of the study timeframe, DB and TB have the same user delays.

Similar to DB, the user delays for TB drop at the beginning of the reconstruction. Until 1998 TB user delays are the lowest among delays from all of the alternatives. From 1998 to 2000 TB delays are nearly equal to DB delays. From 2000 to 2006 TB delays are the highest. They then begin to decrease until in 2008 they reach the same number as DB delays.

7.2.2 Cumulative User Delays

Figure 7.2 shows the cumulative VHD for each reconstruction alternative. NB alternative has the highest cumulative delay. 2001 and 2008 are critical years for overall analysis of cumulative delays. In 2001, the DB alternative is the best alternative for users and remains the best until 2008. In 2008, TB and DB delays reach the same level and NB delays increase significantly over DB and TB. The model estimates that between 1996 and 2010 the DB alternative saves 60 million VHD when compared to the TB alternative.

7.3 Vehicle Miles of Travel

VMT trends do not differ significantly for the three alternatives. Trip routes are virtually the same for each. However, between 2008 and 2009 the VMT for the NB alternative increases rapidly with increased traffic congestion on the road network. If the capacity of the main corridor does not change, extensive rerouting is needed. The rerouting could potentially create longer routes and increase the VMT. Figure 7.3 shows the annual VMT for DB, TB, and NB.

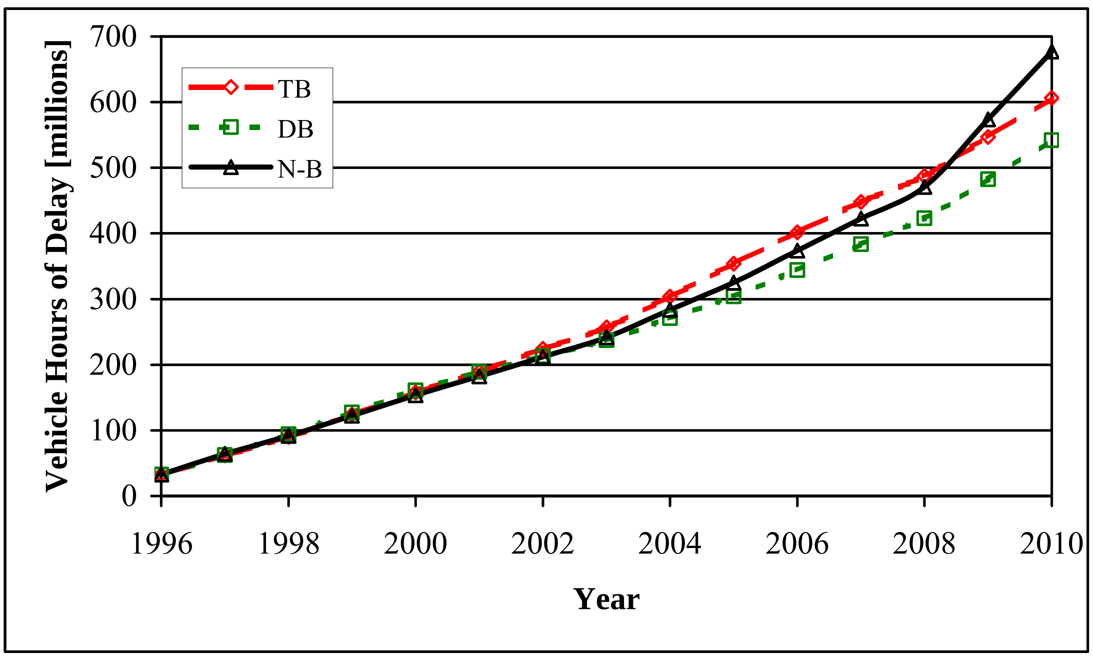


Figure 7.2: Modeled cumulative VHD data

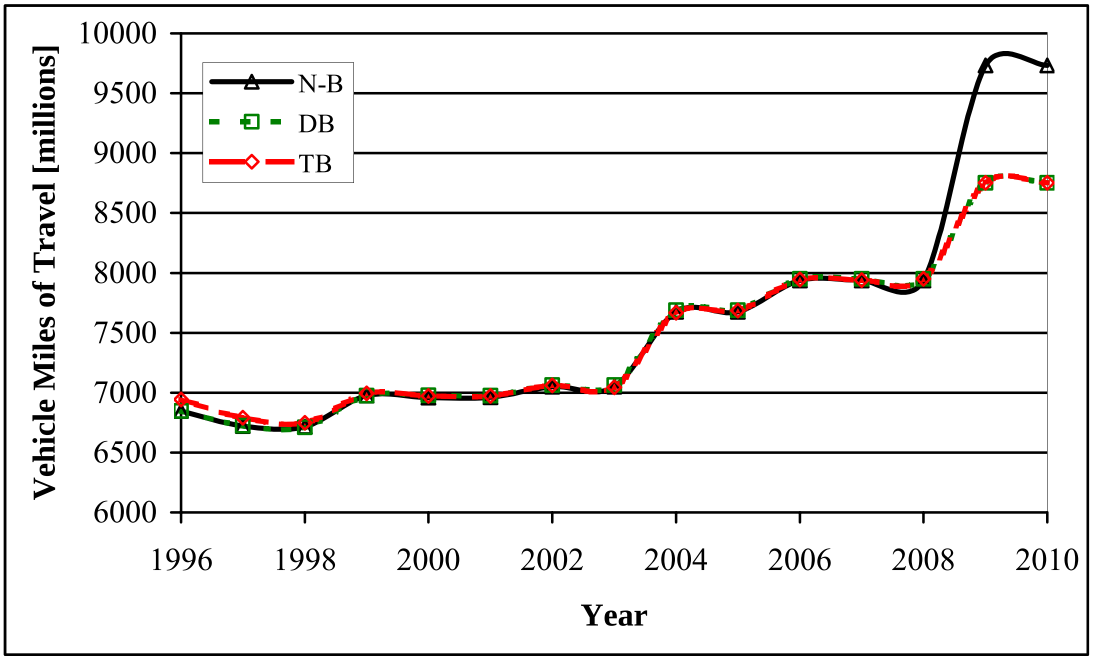


Figure 7.3: Modeled annual VMT data

7.4 Travel Time

Travel time changes for all alternatives are consistent with user delays. Figure 7.4 indicates a correlation between travel time and travel demand on the corridor. For the NB alternative the travel time constantly increases from 1999 to the end of the study timeframe. The initial decrease in travel time from 1997 to 1999 is a result of traffic improvements on the road network that occur independently between 1997 and 1999.

The TB method decreases travel time on the corridor. However, when construction begins in 1997, travel time increases and remains steady until 2003. After 2003, travel time increases more rapidly. However, the interchange and road closures for TB after 2003 do not differ significantly from those before 2003. We conclude that road closures do not impact corridor travel time as significantly as does travel demand.

The DB corridor travel time immediately increases after reconstruction begins. This increase results from the reduced capacity of the I-15 mainline as well as from arterial and interchange closures. Figure 7.4 shows that the negative impact of the closures influences travel time more than the positive impact of improved road capacity. In 1998 the travel time for DB decreases. It becomes considerably lower than travel times for TB and NB. This trend is a result of I-15 segment openings and of completion of certain interchanges and arterials. From 2001 to 2010 travel time depends only on the change in travel demand and increases slowly but constantly. Figure 7.4 shows the I-15 modeled travel times for DB, TB, and NB from 1996 to 2010.

7.5 Network Congestion

Figure 7.5 shows the percentage of the network congestion obtained from the model. Some data in Figure 7.5 is difficult to interpret. The minimal values for DB on the congested links is questionable. All previously mentioned DB MOEs have minimal values in 2001. However, this minimal value occurs in 2002. In 2002 there was no DB construction work. The percentage of congested links is smaller when there is no construction to disturb traffic traffic. Because I-15 was not improved for the NB scenario,

some links on the freeway became congested. In addition to the I-15 congestion, congestion occurred on surface streets due to diverted traffic. These road links were not congested under DB and TB.
Figure 7.5 shows the results for the network under saturated conditions. They indicate the percentage of the links in the network whose V/C ratios are larger than 0.9.

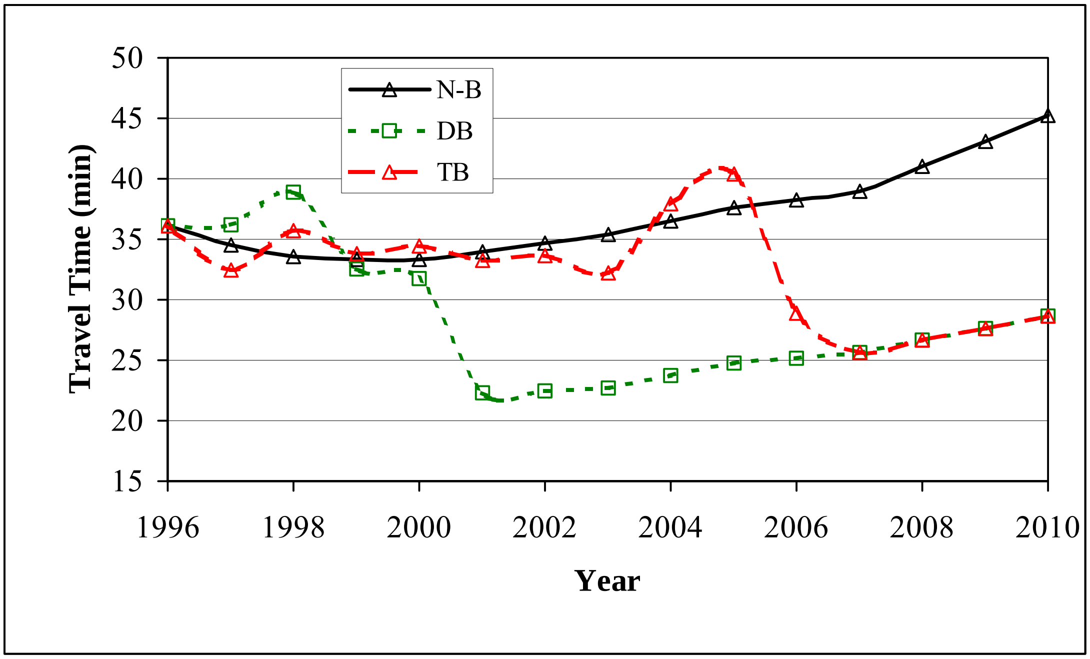


Figure 7.4: Modeled travel time along the reconstructed section of I-15

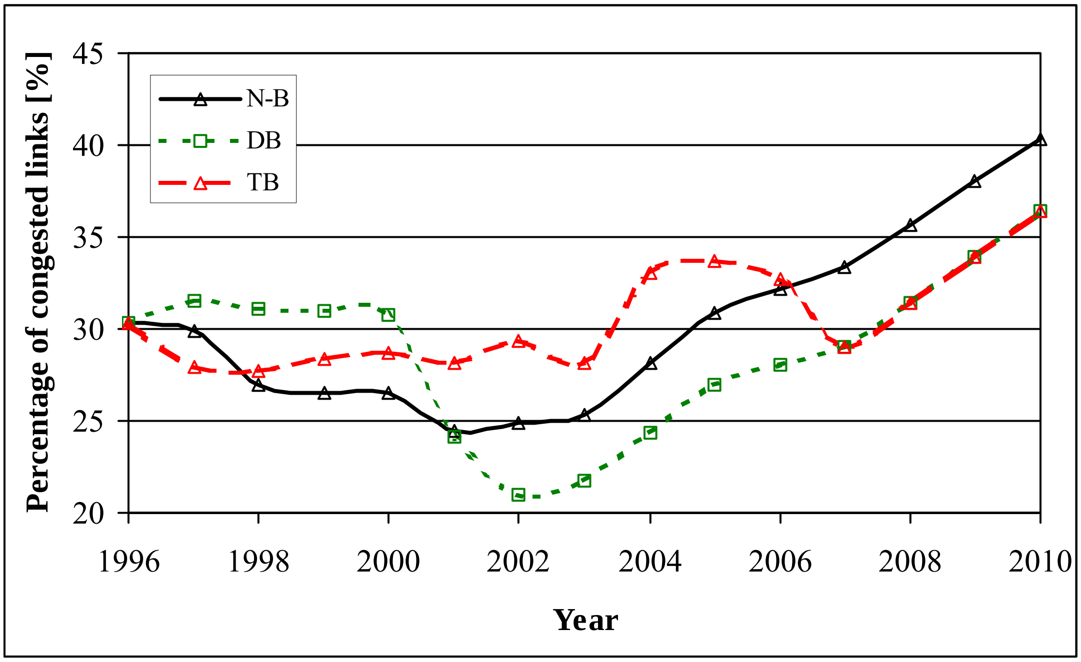


Figure 7.5: Percentage of congested links in the network during PM peak

For NB, the percentage of congested links increases until the end of the study timeframe. The percentage of congested links is the smallest for TB in the first year of the reconstruction. After 2001, TB produces the most congestion. TB congestion levels with DB in 2007. DB produces high congestion until reconstruction is completed. For DB and TB, in 2010 more than 35 percent of the all links would have V/C ratio larger than 0.9 during the PM peak.

7.6 General Findings of the Model

According to the MOEs used in this study, the benefits of the DB alternative outweigh the benefits of NB and TB. Each figure shows that the differences between the areas bound by the TB and DB curves and X and Y axes are always positive. The areas bound by TB curves for any of the MOEs are always larger than the same areas bound by the DB curve. The growth of any MOE represents a negative impact such as traffic delay, travel time, or congestion for users. Therefore, DB is the most efficient alternative for any of the given MOEs.

8. DISCUSSION

8.1 Discussion of the MOE Results

8.1.1 User Delays

Since the N-B reconstruction scenario assumes no reconstruction on I-15 during the study timeframe, there are no user delays resulting from construction-related road closures. In the condition of the road network that does not change over time, user delays should depend (under assumptions of this study) only on the network travel demand. This further means that user delays should remain quite stable for the periods of unchanged travel demand while each higher level of travel demand should bring more delays for drivers.

The user delays for N-B from 1996 to 1997 (Figure 7.1) are the highest because the N-B alternative does not consider some of the capacity increases to mitigate the traffic from I-15 that other two alternatives do assume. These increases in the traffic capacity that were results of the mitigation measures (for example I-215 restriping) would not occur if the reconstruction did not happen. In 1997 the TB user delays are the lowest because the construction in this case would not reach the same level as in the DB case. This means that fewer roads would be closed for the TB scenario, and more capacity would be available for the same travel demand.

From 1998 to 2003 the user delays, for the N-B alternative, are almost constant. This steadiness comes from two reasons: the network remains unchanged, and the travel demands for 1996 and 2000 do not differ very much (travel demands were input from the WFRC). However, from 2002 the N-B alternative stops being the one with the lowest user delays because this year represents the year when the DB reconstruction was finished.

The two building alternatives overtake each other between 1998 and 2001. The DB alternative has the highest user delays for 1998, 1999 and 2000, while the TB alternative's delays are approaching the same level. The difference between delays for these two alternatives can be explained by the amount of road closures affecting the network capacities for each of the alternatives. Although the road closures for TB are steady over the reconstruction time, there are fewer road closures for the DB alternative as the construction work approaches the end. Finally, in 2001 the TB delays become the highest while the DB delays become the lowest.

From 2002 to 2006 two building alternatives keep the same positions while the N-B alternative stays in between them. In 2004 introduction of higher travel demand has a significant influence on the user delays for all three scenarios. This change should be expected to happen gradually over several years, but since the travel demand levels have been estimated for every five years, this influence is evidenced as a sudden increase in delays on the network. However, the impact that increase of travel demand has on the reconstruction scenarios is not shared equally. The alternatives that offer lower traffic capacity produce the higher user delays.

In 2006 the T-B reconstruction would be partially finished and the drivers could experience fewer delays on the partially improved I-15, which makes the N-B the worst alternative in terms of user delays. From this year (2006) to the end of the study timeframe (2010) the N-B alternative remains the worst in terms of user delays. On the other side, the TB user delays start to decrease, and they reach the same level as the DB user delays in 2008 when the TB reconstruction is fully completed.

Again in 2009 an influence of the increase in travel demand becomes evident. This increase has a much stronger impact on the N-B alternative than on the two building alternatives. Figure 7.1 shows this enormous increase in user delays, which indicates that new travel demand would cause significant delays on the existing road network. The DB and TB user delays remain the same until the end of the study time frame (2010).

8.1.2 Vehicle Miles Traveled

The VMT trends (Figure 7.3) do not show large differences among the three alternatives. A logical explanation for similar VMTs lies in the fact that the same numbers of vehicles have to make the same trip lengths for each alternative (for a given year). Basically, only trip routes differ among the alternatives. Unless these routes are significantly different, the VMT should remain approximately the same for each alternative. This logic holds for most of the study timeframe. The only period when the VMT for an alternative significantly differs from others is from 2009 to 2010 (N-B).

For the analysis in this study 2009 was the critical year from many aspects. This year was associated with the 2010-year level of travel demand, and it appeared that the large increase in travel demand became critical for the transportation system, especially for the N-B alternative. The rapid increase in VMT for the N-B alternative can be explained by the increased traffic congestion in the road network. If nothing were changed in the capacity of the main corridor (which was one of the assumption for this alternative), this increased congestion would cause a lot of rerouting in the network. The consequences of the extensive rerouting could be potentially longer routes, which increase the VMT significantly. However, the amount of VMT increase for the N-B alternative shows that travel demand greatly exceeds the existing traffic capacities. From the perspective of traffic assignments (which is based on the shortest time algorithm), this means that many vehicles would take very uncommon routes from their origins to their destinations in order to avoid extremely congested routes. These longer routes increase the overall VMT for the N-B scenario.

8.1.3 Travel Time

For the N-B alternative the travel time constantly increases from 1999 to the end of the study timeframe. Figure 7.4 indicates correlation between travel time and travel demand on the corridor. Since the road network does not change for the N-B alternative, the reasons for increase in the travel time should be sought only in the increase in travel demand over the years. The initial decrease in travel time (from 1997 to 1999) can be interpreted as a result of the traffic improvements on the road network that happened from 1997 to 1999 independently from the I-15 reconstruction. These improvements on the roads parallel to I-15 provided new or better travel opportunities for some of the I-15 users. Finally, the improvement resulted in the decrease of travel demand on the I-15 corridor, which further decreased the travel time on the corridor.

The TB method, similar to the N-B method, initially decreases the travel time on the corridor. However, when the construction starts (1997), this scenario maintains the corridor travel time steady, with small variations between 1998 and 2003. These variations tell about significance of the impact that the pair of interchanges that were closed during that specific period has on the travel time along the I-15 corridor. From 2003 the travel time increases mainly due to the increase in the travel demand level. Since the interchange and road closings after 2003 are not very different from those before the 2003 one can conclude that the impact of the road closures is much less important on the corridor delay than changes in the travel demand. The travel time for TB alternative reaches the maximum (around forty-one minutes) in 2005 and then starts to decrease. In 2006 the TB reconstruction approaches its end, and the travel time is slightly higher than for DB scenario. In 2007 all construction works for TB alternative are finished and the travel time gets the same value as one of DB alternative. From 2007 to the end of the study timeframe the TB corridor travel time constantly grows with the increase in travel demand.

The DB corridor travel time immediately increases after the beginning of the reconstruction. This increase results from the reduced capacity of the I-15 mainline as well as from arterial and interchange closures. Figure 7.4 shows that the negative impact of the closures has more influence on the travel time than the positive impact of the improved capacity on the certain roads (traffic mitigation measures). The maximum travel time for the DB alternative is reached in 1998 (around forty minutes). From this point the travel time decreases and becomes considerably lower from potential travel time for other two alternatives. This trend can be explained by openings of some I-15 segments and completion of certain interchanges and arterials. Finally, the travel time in 2001 reaches the minimum value for all three alternatives (around twenty-two minutes). From 2001 to 2010 the travel time depends only on the change in travel demand, and thus it increases slowly but constantly.

8.1.4 Network Congestion

The results for the percentage of the network congestion obtained from the model and shown in Figure 7.5 are the most difficult to correctly interpret from all of the MOEs. There are several points in Figure 7.5 that cannot be easily explained using only common logic.

The first thing that can be questioned is the minimum value for the DB percentage of the congested links. All previously mentioned DB MOEs have minimal values in 2001, yet this minimal value occurs in 2002. A reason for this exclusivity is that the percentages of the congested links for each year actually represent percentages of the congested links during the PM peak for a representative month for a certain year. In the case of the year 2001 a representative month cannot be a month when all construction work are finished, since a half of the year there was still ongoing construction work. On the other side, in 2002 there was no construction work (no congested roads caused by work zones), hence this year represents the first full year with all the benefits from the reconstructed I-15. Since the percentage of the congested links will be smaller when there is no construction to disturb the traffic, it is evident that the minimal value will be obtained for the year with the least construction work and the least travel demand, which is indeed the year 2002.

The second uncommon feature of Figure 7.5 represents a parallelism between the N-B and DB/TB trends after the end of the TB reconstruction. To explain this feature let us first explain the meaning of this MOE again. The percentage of the congested links was adopted as a general estimate of the network performance during the PM peak periods for three reconstruction scenarios over the study timeframe. It represents the ratio between links with the V/C ratio larger than 0.9 and all links in the network.

Let us, for example, compare two cases of the same network loaded with the PM peak traffic based on the given travel demand. In the first case only two links with small traffic loads (e.g., 2000 vehicles/link/PM peak) have the V/C larger than 0.9. In the second case only one link in the whole network is under congestion (V/C>0.9). However, this link is a part of a freeway and has a volume of more than 18,000 vehicles/link/PM peak. Although the congestion in the second case is more relevant from the system congestion perspective than the first case congestion, the first case will have a higher percentage of the congested links because two links are congested compared with only one in the second case.

Considering this principle one can conclude from Figure 7.5 that the difference in the percentages of congested links for the alternatives (N-B and TB/DB) in 2007 represents the number of links congested only for the N-B scenario due to insufficient capacity on I-15. In other words, because I-15 was not improved for the N-B scenario, some links on the freeway became congested. In addition to the congestion of the I-15, the original I-15 travelers used other arterial roads to avoid congestion on the I-15 and shorten their trips. These two factors caused some road links in this scenario to become congested, which otherwise, in the TB or DB alternative, would not be congested. Once this difference in number of congested links is set (when construction is finished for each alternative - 2007) it remains the same for future years. This actually means that the number of congested links would equally increase for both the N-B and TB/DB alternatives. After the travel demand overcomes the capacity of the reconstructed I-15, the TB/DB lane will likely change slope. However, since these two lines started from different points, in terms of the available capacity, a certain difference in the percentage of the congested links will always exist.

8.2 General Discussion

8.2.1 Temporal Reconstruction Aspects

This study finds DB to be the best of the three alternatives for minimizing user delays. This is because travelers are exposed to insufficient road capacity for a shorter time period. The TB alternative shows the same improvements in capacity on the corridor, but only after ten years. The NB alternative does not improve capacity. An area with growing travel demands benefits more from rapid construction.

8.2.2 Spatial Reconstruction Aspects

During DB reconstruction the I-15 mainline capacity was reduced to two lanes per direction. Interchanges were also reconstructed. This caused partial closure of multiple interchanges during certain time intervals of the I-15 project. This type of reconstruction caused several small bottlenecks and reduced the corridor capacity.

With TB there is no need to reduce capacity on more than two sections at the same time. This type of reconstruction does not cause more than one or two significant bottlenecks on a corridor with closed interchanges.

8.2.3 Other Reconstruction Aspects

Actual construction for the TB and DB alternatives would require a similar amount of work. However, management strategies for the two projects affect their length. The TB alternative requires many contractors. This causes coordination issues and project delays. In contrast, the DB reconstruction alternative used one contract and minimized construction time. It also used resources from other states. Its employment of external labor and equipment enabled contractors to work 20 hours per day and finish the project in five years. With TB construction, the average workday does not exceed eight to ten hours.
The governor initiated the DB alternative and it was strongly supported by the public and state administration. Support continued throughout the project. However, if the project had lasted longer than the governor's term in office, funding for the project would likely change.

9. CONCLUSIONS AND FUTURE RESEARCH

9.1 Conclusions

The findings from this study show that the calibration of the traffic assignment results is generally successful. The federal recommendation for the coefficient of determination (0.9) is not achieved, but the results are still acceptable (0.8). Inaccuracy in the calibration and validation results of the study is due to the OD tables.

The following null hypotheses were rejected:

1. $H_{0(1)}$ - The total user delay costs are higher for the Design-Build alternative than for the No-Build alternative.
2. $H_{0(2)}$ - The total user delay costs are higher for the Design-Build alternative than for the Traditional-Build alternative.
3. H0(2) - The total user delay costs are higher for the Traditional-Build alternative than for the No-Build alternative.

This study indicates that the DB method is better than TB and NB in terms of user delay costs, corridor travel time, and network congestion. It also indicates that any active construction alternative is better than no construction.

An increase in travel demand has more significant impacts on total user delay costs than do extensive road closures. Between 1997 and 2001 there is little difference in user delays, corridor travel time, and overall congestion for the DB and TB alternatives. This indicates that the TB, with its pairs of traffic system bottlenecks creates nearly the same level of user delays as the extensive closures of the DB alternative.

9.2 Limitations of the Research and Future Research Opportunities

The study models traffic assignment based on trip tables from WFRC. Accuracy of calibration and validation results could improve if the trip tables better represented trips between the zones. Significant attention was given to model calibration. However, the three initial steps were conducted outside of the traffic lab. This limited opportunities to improve model calibration.

Model representation of real traffic conditions was also limited. Transportation network data could more accurately represent real world conditions. Travel times and speeds on links were not associated with traffic control at intersections. New versions of VISUM do consider traffic signal impedances on traffic performance. These impedances could be included in the overall impedances on the road network. Interface use between VISUM and VISSIM would likely benefit smaller networks. However, the actual benefits have not yet been estimated.

The feedback connection between travel demand and traffic supply is limited as well. The travel demand forecast for all alternatives assumed that I-15 capacity would improve by the end of the study period. However, if no reconstruction occurred, the travel demand on I-15 may not have the same growth rate the travel demand for DB and TB. This study limitation presents a question for further research. Did we overestimate NB user delay costs by assuming that travel demand would be higher than if I-15 had not been reconstructed? The same question can be asked of the TB alternative. Would travel demand remain the same for both DB and TB between 1996 and 2010?

Future research should also address the number and size of the reconstruction contracts in order to estimate the benefits of DB. How would DB function if it was not controlled under a single contract but under a number of smaller and shorter DB contracts? In addition, would these smaller DB contracts cause more or less disruption to travelers than TB?

Future research should also address the impact of different contracting methods on user costs under a constant travel demand. User delays for DB and TB should be studied with no growth in travel demand to show the advantages and disadvantages of different road construction schedules.

10. TRAFFIC ACCIDENT ANALYSIS

10.1 Introduction

When the I-15 project began on April 15, 1997, increased travel times, queues, congestion, and accidents became common driving experiences. Public support for the project declined. News media reported that people were concerned about increased accident numbers on streets surrounding I-15 reconstruction areas. On January 7, 1998, a *Salt Lake Tribune* article entitled, *Communities Seek Help With Traffic Trouble* stated that "30 percent of Interstate 15 traffic [had] poured onto city streets," that there was a "300 percent jump in automobile accidents," and that "Police Department overtime expenses [had] jumped 87 percent." Though these numbers may be inflated, reconstruction did significantly impact Salt Lake County drivers. This study assesses the impact of DB and TB on accident numbers and vehicle emissions to determine the safest reconstruction method for I-15.

10.2 Literature Review

Such a project as the I-15 reconstruction may cause traffic congestion and increased travel time. In addition, work zone setups and diverted traffic may alter some drivers' behavior. These factors and whether or not they impact accident numbers are addressed in traffic-study literature.

Robertson et al [6] examined the effects of a major reconstruction project in Montreal, Canada. The Autoroute 40, a six-lane elevated roadway that carries about 140,000 vehicles per day, is the only east/west expressway in the Montreal area. Reconstruction of Autoroute 40 covered a length of 6.8 miles. Most of the project enforced full lane closure for at least one of the directional lanes, resulting in a total fifty to sixty percent capacity reduction. Robertson found that eight intersections adjacent to Autoroute 40 significantly decreased the level of service they provided; many of them dropped from a level A or B to a level F. This study shows how lane closures may significantly affect traffic patterns. Although accidents were not directly addressed in this study, changes in traffic patterns may affect the number of accidents occurring.

In another article Rouphail et al [7] researched the effects of work zones on traffic accidents. This study examined accidents over a six-year period (1980-1985) and how they were influenced by three long-term construction projects and 23 short-term construction projects. The study concluded that accident severity decreased during the construction period. In addition, there was a 20% decrease in fatal accidents. However, rear-end accidents increased by about 50%. Multiple vehicle accidents increased by about 15%.

A study by Worsey, G. [14] used regression analysis to determine the causes of intersection and non-intersection accidents. Yearly accident numbers are determined by number of links, flow, headway, pedestrian volumes, and conflict points. These factors describe road layout, infrastructure, and traffic flow.

Baruya, A. [1] summarized the results of studies comparing accidents and speed on different road types. This study considered research theories from 1964 to 1997 and concluded that a reduction in accidents occurs when mean speed decreases. The researcher also found a relationship between accidents and variance in speed at both low and high speeds.

Zlatoper, T. [15], surveyed research on motor vehicle deaths in the United States and focused on the study, "The Effect of Automobile Safety Regulations" conducted by Peltzman in 1975. Zlatoper critiqued the study's economic model of motor vehicle deaths and reviewed further attempts to specify a model for motor vehicle deaths. Most accident studies use regression analysis models. They have variables in price, income, alcohol, speed, youth, vehicle miles of travel, proportion of motorcycles, and trucks. A major critique of Peltzman is that he uses death rate instead of number of deaths as a dependent variable. The use of a death rate may have resulted in spurious correlation as vehicle miles were the denominator of the dependent variable. This paper focuses on the main variables that determine accident rates and summarizes the effort of past research in relation to the estimation of number of accidents.

Sisiopiku, V. et al [8], examined hourly accident rates and hourly traffic volume in relation to capacity (v/c) ratios. Researchers studied a sixteen-mile segment of the Interstate I-94 in Detroit between 1993 and 1994. They collected volume to capacity ratios using three permanent count stations. The researchers found that the correlation between v/c values and accident rates follows a U-shape pattern. Therefore, the study indicates that accident rates are highest in the very low hourly v/c range, decrease with increasing v/c ratio, and then increase as the v/c ratio continues to increase. It also shows that congestion measured as v/c ratio effects accident rates and follows a U-shape pattern.

There has not yet been a comprehensive study addressing accident rates under different construction methods. A vast amount of literature exists on the relationship between accidents and traffic variables and on the effects that construction has on traffic in work zones. However, this study is the first to examine the effects of different construction methods on accident rates at a macroscopic level.

10.3 Study Area

This project studied freeways, principal and minor arterials, and collector roads in the Salt Lake Valley. This network was used to estimate basic transportation metrics and traffic emissions. However, it was not suitable for traffic accident study.

The model used to estimate accident number assumes that accidents increase as traffic volume increases. However, in Salt Lake County VMT increased while accident number decreased between 1994 and 2001. This is because safety programs and law enforcement worked together to decrease accident numbers. Due to these external factors, it was not possible to determine the effect of I-15 reconstruction on accident number.

The effect of construction on accident number is obscured when data is analyzed for a large study area. A decrease in accident number on I-15 along with an increase in the number of accidents on surrounding streets would not be detected at the county level. Therefore, the study area was downsized to I-15 and the following major north-south routes:

- Interstate 15
- Interstate 215 East of I-15
- Interstate 215 West of I-15
- State Street
- Bangerter Highway
- Redwood Road
- 700 East

Figure 10.1 is a map of the routes examined in this study. However, the whole county is considered the study area for emission analysis. Once emission factors are modeled they are multiplied by the VMT for all roads to find emission inventories for the county network.

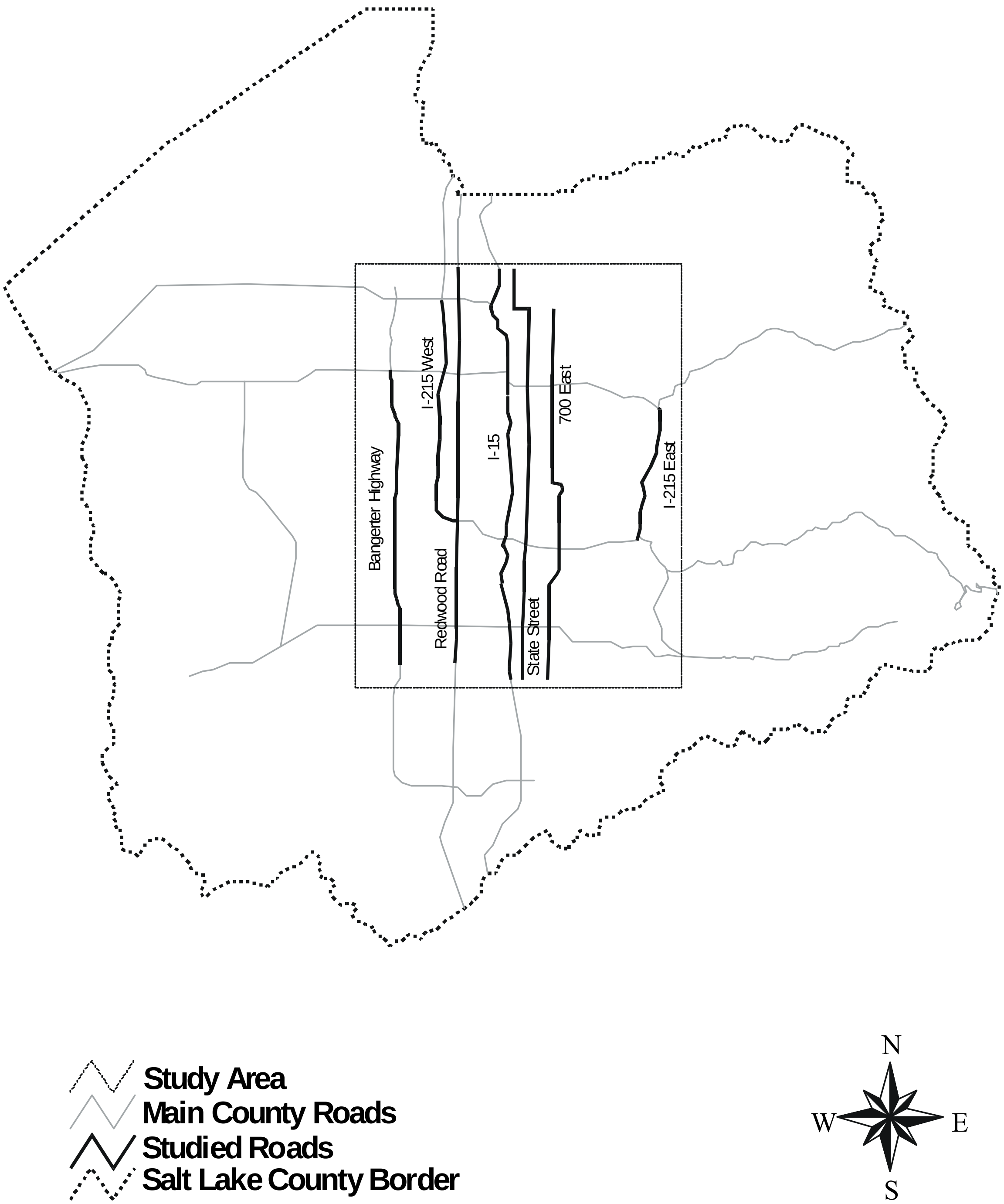


Figure 10.1: Major north-south routes examined

10.4 Methodology

Multiple systems collected data for this study.

10.4.1 Data

10.4.1.1 Centralized Accident Records System (CARS)

The Utah Department of Transportation's (UDOT) CARS database provides traffic accident data at the individual street level. The City Police Department and highway patrols collect the data. This study considers the following information from the database:

- Route number – identifies streets on the network
- Mile point – identifies sections within a particular street.
- Accident severity – describes the accident severity as no injury, possible injury, bruises and abrasions, broken bones to bleeding wounds, and fatality.
- Number of vehicles involved
- Accident date and time

10.4.1.2 Crash Outcome Data Evaluation System (CODES)

The Crash Outcomes Data Evaluation System (CODES) provides traffic accident data for Salt Lake County as a whole. In 1992, The National Highway Traffic Safety Administration (NHTSA) funded CODES to link different traffic accident databases. CODES allows analysis of accident data and accident consequences, such as emergency response time and medical outcome. UDOT, the Utah Department of Health, and the Bureau of Emergency Medical Services provide CODES data. This data is available for Salt Lake County as a whole between 1992 and 2001.

10.4.1.3 Traffic on Utah's Highways

Traffic on Utah's Highways provides AADT counts for road state highways, federal-aid urban local highways, and federal-aid secondary local highways. The data is collected by UDOT through 97 continuously operating permanent automatic traffic recording stations, approximately 5,250 short-time counters for the Highway performance monitoring system, and 14 seasonal counters. Traffic on Utah's Highways provides data for 1991 to 2001.

10.4.1.4 VISUM

The VISUM model provides derived data. It predicts past and future traffic assignments for DB, TB, and NB between 1996 and 2010. The VISUM model estimates variables such us volume, speed, and congestion. The model day is divided into morning, mid-day, afternoon period, early evening, and late evening. The network considers changes in traffic, demand levels, and street and interchange closures. DB, TB, and NB were modeled with a total of 83 VISUM runs.

10.4.2 Measures of Effectiveness (MOEs)

Traffic accident number and accident rate are the two Measures of Effectiveness (MOEs) used to compare the three alternatives. VMT reflects differences in accident numbers and road use. Accident rate is the number of traffic accidents per 100 million-vehicle miles of travel:

$$RMVM = \frac{A * 100{,}000{,}000}{VMT} \qquad [1]$$

Where:
RMVM = Accident rate per 100 million vehicle miles of travel
A = Number of accidents

VMT = Vehicle miles of travel

10.4.3 Regression Model

A regression model was used to determine accident numbers for DB, TB, and NB based on different traffic variables. Regression analysis in this study estimates accident number from VMT, congestion, and interchange closure data. The regression model is based on real data and outputs from the transportation-planning model. It was calibrated with traffic data from 1996 to 2001 using the MS Excel multi-regression analysis tool. Equation [2] is the multi-regression equation used in this study.

$$A = a + \beta_1 * MVMT + \beta_2 * Const + \beta_3 * Inter + \beta_4 * Cong \qquad [2]$$

Where:
A = Number of accidents
α = Intercept (regression parameter)
β_I = Partial slope coefficient (regression parameter)
MVMT = Million vehicle miles of travel
Const = Length of the work zones on I-15
Inter = Number of interchanges open on I-15
Cong = Congestion in the network

$$Y = a + \beta_1 * MVMT + \beta_2 * Const + \beta_3 * Inter + \beta_4 * Cong \qquad [3]$$

Where:
Y = Number of accidents per season
A = Intercept (regression parameter)
β_I = Partial slope coefficient (regression parameter)
MVMT = Million of vehicle miles of travel
Const = Length of the work zones on I-15
Inter = Number of interchanges open on I-15
Cong = Congestion in the network

10.4.3.1 Variables

10.4.3.2 Vehicle Miles of Travel (VMT)

VMT describes road use and is one of the most important variables used to estimate accident number. For calibration purposes, VMT is obtained by multiplying the Annual Average Daily Traffic (AADT) on a road by the length of the relevant road section. VMTs are obtained from spreadsheet calculations of VISUM traffic assignment outputs. Modeled VMT data is used to estimate the accident number for DB between 2002 and 2010 and to analyze NB and TB between 1996 and 2010. As VMT increases, the number of accidents is expected to increase.

10.4.3.3 Construction

Construction, as a variable, represents the length of the road under construction. This variable was used by Rouphail *(5)* to determine the number of accidents at work zones. As the length of work zones increases, the number of accidents is expected to increase. In this study the construction variable accounts only for accidents related to I-15 reconstruction work zones. Data for this variable is obtained from the VISUM network files. The network was changed every time reconstruction activities required that a link or an intersection open or close.

10.4.3.4 Number of Interchanges Open

When I-15 reconstruction began, work on some of the interchanges also started. Reconstruction of an interchange requires its partial or full closure. This increases the possibility that a driver will choose an alternate route. Number of open interchanges determines the effect of closures on accident numbers. Because highway traffic decreases and interchanges close, construction is expected to decrease the number of accidents on I-15. Table 10.2 shows these movements.

Table 10.1: Movements at an Interchange

Movement	Coming From	Going To
1	North	East
2	North	West
3	South	East
4	South	West
5	East	North
6	East	South
7	West	North
8	West	South

An index measures the effect of construction on an interchange. In Equation 4, each possible movement is assigned a value of one-eighth. The index is the interchange functionality during reconstruction. It is determined by multiplying the number of movements allowed at an interchange by its value (one-eighth). Index values of zero and one represent a fully closed or fully open interchange.

$$Interchange\ Index : M * \frac{1}{8} \qquad [4]$$

Where:
M = Movements allowed
Based on the assumption that as diverted traffic increases the number of accidents also increases, it is expected that construction would cause an increase in the number of accidents on surface streets. However, construction is expected to lower the number of accidents on I-15. As more interchanges close, highway traffic decreases. This decreases the number of accidents.

10.4.3.5 Congestion

I-15 reconstruction increases traffic congestion on its surrounding routes. In general, accident number increases as congestion increases (*6*). Congestion, as a variable, represents the percentage of network links with volume/capacity ratios higher than 0.9. Congestion percentages for this study came from VISUM output files.

10.4.3.6 Calibration

Mathematical models determine causal relationships between variables. The regression model in this study considers the number of accidents per season as the dependent variable (Y) and VMT, interchanges, construction, and congestion as the independent variables (Xs). Equation 5 expresses these variables.

$$Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 \qquad [5]$$

Where:
α = Intercept (regression parameter)
β_I = Beta coefficient of variable i (regression parameter)
Y = Number of accidents per season
X_1 = Vehicle Miles of Travel
X_2 = Number of interchanges open
X_3 = Length of road under construction
X_4 = Congestion in the network

For each value of the dependent variable Y_i the model estimates a value for $\hat{Y}_i$. The difference between Y_i and $\hat{Y}_i$ is the error of the fitted line. In order to determine a good fit between the regression model and the observed values, the sum of square errors must be minimized. Equation 6 shows the least square criterion.

$$Min \quad \sum_{i=1}^{n}(Y_i - \hat{Y}_i)^2 \qquad [6]$$

Where:
Y_i = Observed value
$\hat{Y}_i$ = Fitted value from the regression model

Squaring emphasizes large errors and helps avoid them. The two parameters associated with regression analysis, alpha intercept (α) and betas (β), are calibrated by the software so that the least square criterion is met. This means that the sum of the errors is minimal. The alpha intercept (α) represents the value of the dependent variable when all the independent variables are zero. The betas (β) or partial slopes represent change in the expected value of the dependent variable (Y). This is associated with a unit increase in a particular independent variable (X_i), when all other independent variables are held constant. The coefficient of determination (R^2) is the total variation in the dependent variable (Y) determined by its linear relationship to the independent variables (Xs). This parameter ranges from zero to one. An R^2 of one is a perfect model that determines all variations in the dependent variable (Y). Therefore, an R^2 of 0.54 indicates that the model describes 54% of the variation in the dependent variable.

10.4.3.7 Statistical Analysis

The statistical test in regression analysis helps determine the accuracy of the model. The null hypothesis associated with the coefficient of determination (R^2) is that none of the dependent variable's variation can be attributed to its linear relationship with the independent variable. This indicates that the R^2 of the model is zero. This model does not explain any variation in the independent variable. The statistical test associated with the null hypothesis is the Fisher distribution with one and N-2 degrees of freedom. N is the sample size. If the calculated value of F is larger than the critical value for the chosen probability level, then the null hypothesis is rejected. Therefore, the coefficient of determination (R^2) of the model is significantly different than zero. This study uses a 95% confidence level.

The null hypothesis for the alpha intercept (α) and the betas (β) is that the population parameter (α or β) is zero. The coefficient does not explain any variation in the dependent variable (Y). For example, if the regression model shows that the coefficient associated with variable congestion has a high probability of being zero, the variable should be removed from the regression model. Therefore, another model should be used without the variable. The Student's t test distribution with N-2 degrees of freedom tests the null hypothesis where N is the sample size. This value depends on the confidence level and the number of observations included in the regression. This study uses a 95% confidence level.

10.4.4 Assumptions

This study uses modeled data from VISUM to determine the number of accidents for DB, TB, and NB. No changes in vehicle technology, such as automated guided systems or brake technology could modify existing accident trends.

10.4.5 Data Analysis and Methodology by Aggregation Level

10.4.5.1 Salt Lake County

This study area considers all routes within Salt Lake County. Table 10.2 shows data types, sources, and data time periods. Modeled VMT was used when VMT data was not available.

Table 10.2: Salt Lake County Data Description

Data Set	Period of Time	Source
Number of Accidents	Month	CODES
VMT (DB 1996-2001)	Year	UDOT
VMT	Season	VISUM
Congestion	Season	VISUM
Number of Interchanges Open	Season	VISUM
Construction	Season	VISUM

Most data sets are available or can be grouped on a seasonal basis over a period of three months. Table 10.3 shows months grouped by season.

Table 10.3: Seasons and Months

Season	Months
Winter	January, February, and March
Spring	April, May, and June
Summer	July, August, and September
Fall	October, November, and December

However, VMT from UDOT is available on a yearly basis only. All data sets should represent similar time periods in order to keep regression results consistent. It is ideal to have many data points so that the model can provide better results. Ideally, all data sets represent a month. The process of disaggregating data is difficult. Therefore, the second best alternative is to consider data by season. The main challenge in this case is to transform VMT from years into seasons. UDOT provides Average Daily Traffic (ADT) counts on a monthly basis for selected locations within the Salt Lake County area. Three automatic counter stations within the county were selected for this study according to their proximity to the I-15 project and their adequate data coverage between 1996 and 2001. Table 10.4 and Figure 10.2 show the location and description of the selected counter stations.

Table 10.4: Counter Location Description

Station	Route
35-0354	SR-171 3300 South 1176 West
35-711	SR-154 2500 South Bangerter Highway
35-0302	I-15 0.5 miles south of Draper Interchange

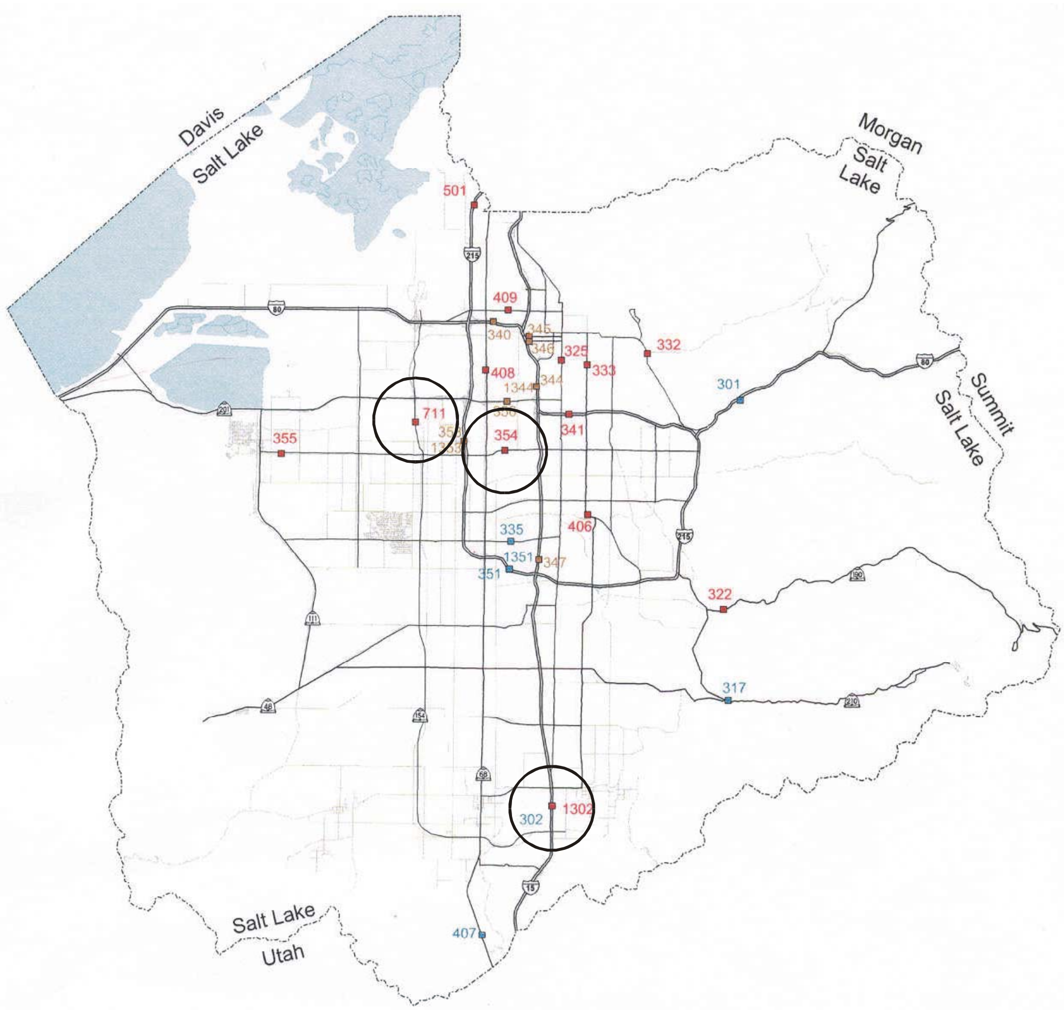


Figure 10.2: Permanent Counter Locations

Figure 10.3 shows monthly variations in VMT during 1996. VMT varies throughout the year and peaks in May and August. A similar procedure was performed from 1997 to 2001. The average of the three stations was used as pattern for the county's VMT variation. The average monthly variations calculated for the three counters were assumed to represent Salt Lake County's VMT variation. Although this may not accurately determine VMT variance for the entire county, it can approximate the variance. When all of the data was aggregated to the same time period it was used to calibrate the regression model.

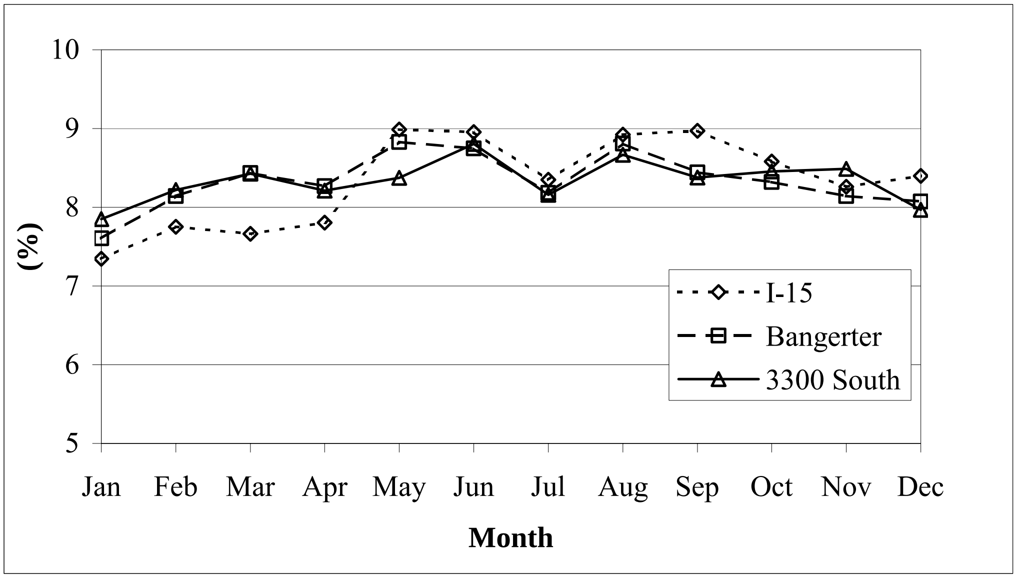


Figure 10.3: ADT Variance by Month in 1996

10.4.5.2 Major North-South Routes

This study considers seven major north-south routes near the I-15 reconstruction area.

Table 10.5 shows the study's data type, data source, and aggregation level for these routes.

Table 10.5: Major North-South Routes Data Description

Data Set	Period of Time	Source
Number of Accidents	Daily	CARS
AADT (DB 1996-2001)	Year	Traffic on Utah's Highway
VMT	Season	VISUM
Congestion	Season	VISUM
Number of Interchanges Open	Season	VISUM
Construction	Season	VISUM

The CARS database provides accident data for each of the examined routes. Each route was queried between 1996 and 2001. AADT data and a description of route sections are available on Traffic on Utah's Highways. VMT can be determined by multiplying AADT by a section's length. Daily VMT is multiplied by 365 days to find annual VMT. Network congestion, number of interchanges open, and length of the construction on I-15 were determined from the VISUM model. These parameters were obtained through a set of queries that retrieved data from specific links within the network.

A graphical analysis of data from 1996 to 2001 shows a difference in highways and surface streets. These two road types cannot be included in the same regression analysis because they belong to different road functional classes.

There were 44,952 accidents between 1994 and 2001 on the seven major north-south routes. Surface streets, such as 700 East, Redwood Road, and State Street account for more than 60% of the total accidents among the major north-south routes. The percentage of accidents on I-15 decreased by 34% during reconstruction because the freeway was partially closed and traffic was diverted onto the surrounding routes. The decrease in accident number on I-15 was compensated by an increase in accident number on all other routes. Accident number on I-215 West increased by 76%. Accident number on State Street increased by 27%. Figure 10.4 shows each route's contribution to annual accidents rates. Figure 10.5 shows each route's contribution to the total annual VMT. It shows that highways such as I-15, Bangerter Highway, and I-215 contribute to more than 70% of the vehicle miles traveled between 1994 and 2001. There was a 42% decrease in VMT on I-15 during the construction period. This decrease in VMT was followed by a VMT increase on all other routes. I-215 West increased its VMT by 50% during the period of reconstruction as compared to 1994 to 1996.

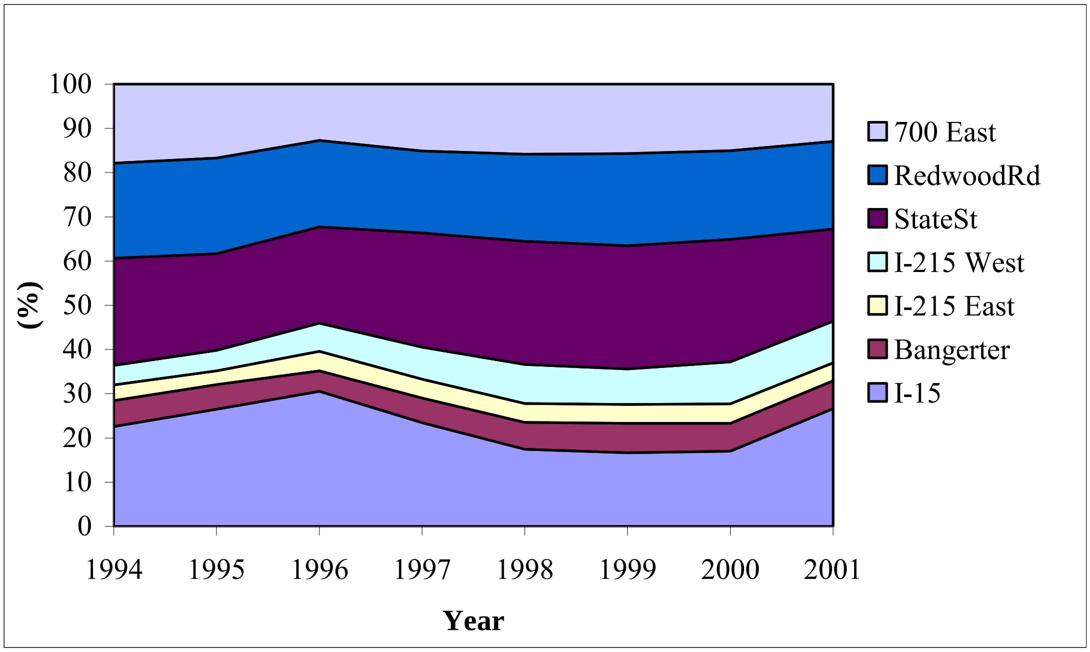


Figure 10.4: Contribution to Annual Accidents 1994-2001

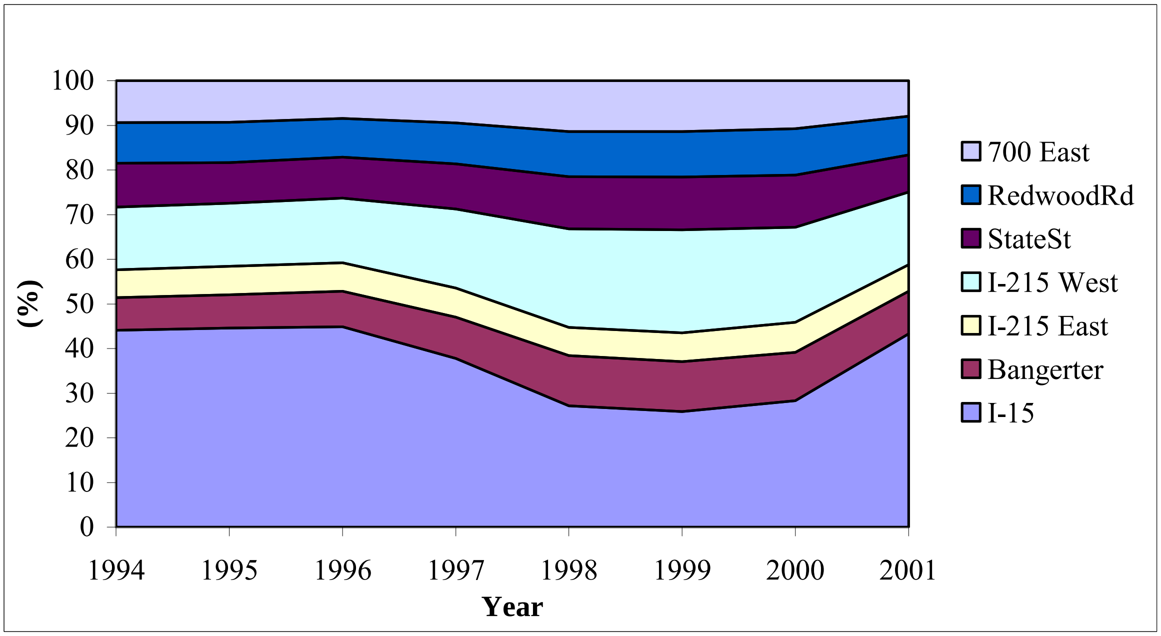


Figure 10.5: Contribution to Annual VMT 1994-2001

Figure 10.6 shows the relationship between accident number and VMT. There is a low VMT with a high number of accidents on all surface streets. There is a high VMT with a high number of accidents on all highway routes. VMT has a greater impact on surface streets than on highways. This is because surface streets have a smaller capacity, signalized intersections, and a lower speed limit. Two regression models were calibrated based on the graphical analysis, one for highways and the other for surface streets. Traffic on Utah's Highways and VISUM provide VMT data for DB between 1996 and 2001. Data from both sources was compared to determine that VISUM produced acceptable values. The comparison was performed for each major north-south route. Table 10.7 shows the average overestimation between the existing and the modeled VMT.

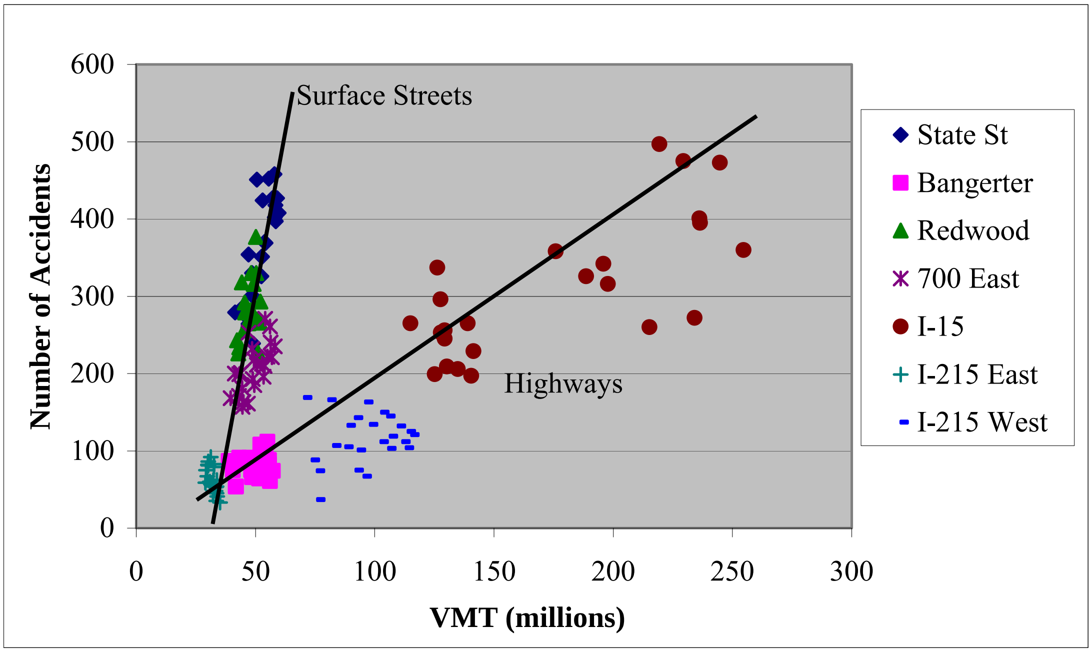


Figure 10.6: Accidents per Season vs. VMT for Major N-S Routes, 1996-2001

Table 10.7: Comparison of Modeled and Existing VMT

Route	Overestimation (%)
I-15	15
I-215 East	14
I-215 West	53
Bangerter Highway	9
Redwood Road	0
State Street	24
700 East	59

VISUM overestimates VMT values for all routes but Redwood Road. The largest overestimations occurred on I-215 West and 700 East. Modeled values were nearly 60% higher than observed values. The average overestimation for each route between 1997 and 2001 was used to correct modeled VMT. It can be assumed that VISUM would also overestimate VMT for those routes when considering TB and NB. After 2002 modeled data only exists for 2003, 2005, 2007 and 2010. VMT for other years was interpolated.

10.4.5.3 I-15 Corridor

In this study, State Street, Redwood Road, and 700 East are surface streets. I-215 East, I-215 West, SR 201, and Bangerter Highway are highways. And, I-15 is the corridor between 600 North and 10600 South. Figure 10.7 shows the number of accidents on highways, surface streets, and I-15 between 1994 and 2001. During reconstruction, the number of accidents on surface streets and highways increased. The increase was more noticeable for the surface streets. Accident number on I-15 decreased during reconstruction due to decreased VMT.

Figure 10.8 shows changes in VMT during reconstruction. VMT on I-15 decreased considerably. In 1996, over 40% of traffic was diverted from I-15 and absorbed by surface streets and other highways. Traffic on surface streets increased by 15%. Traffic on highways increased by 30%.

Figure 10.9 shows the accident rate and the number of accidents per 100 million VMT for each group of routes. Accident rate slightly increased during reconstruction. A student's t test determined the significance of this increase. It was found insignificant at a 95% confidence level. Figure 10.9 also shows that the accident rate for highways remained nearly the same throughout reconstruction. However, a large portion of traffic diverted from I-15. Both accident number and VMT decreased during reconstruction. However, accident rate slightly increased due to an increase in accidents at work zones. This increase was not statistically significant at a 95% confidence level.

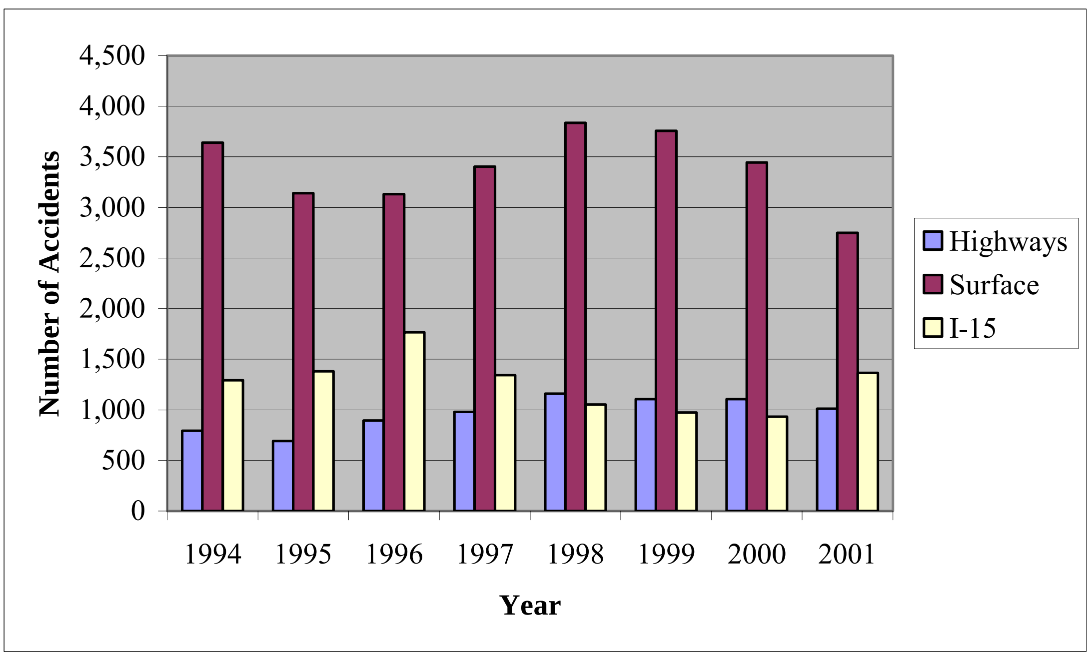


Figure 10.7: Number of Accidents by Roads

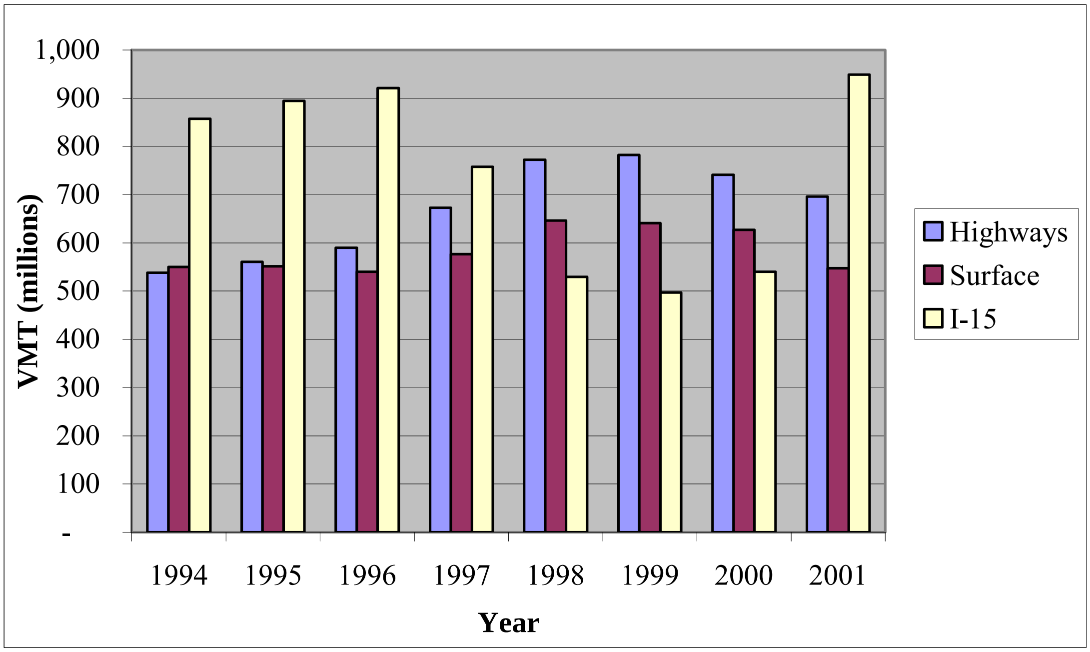


Figure 10.8: VMT by Roads 1994-2001

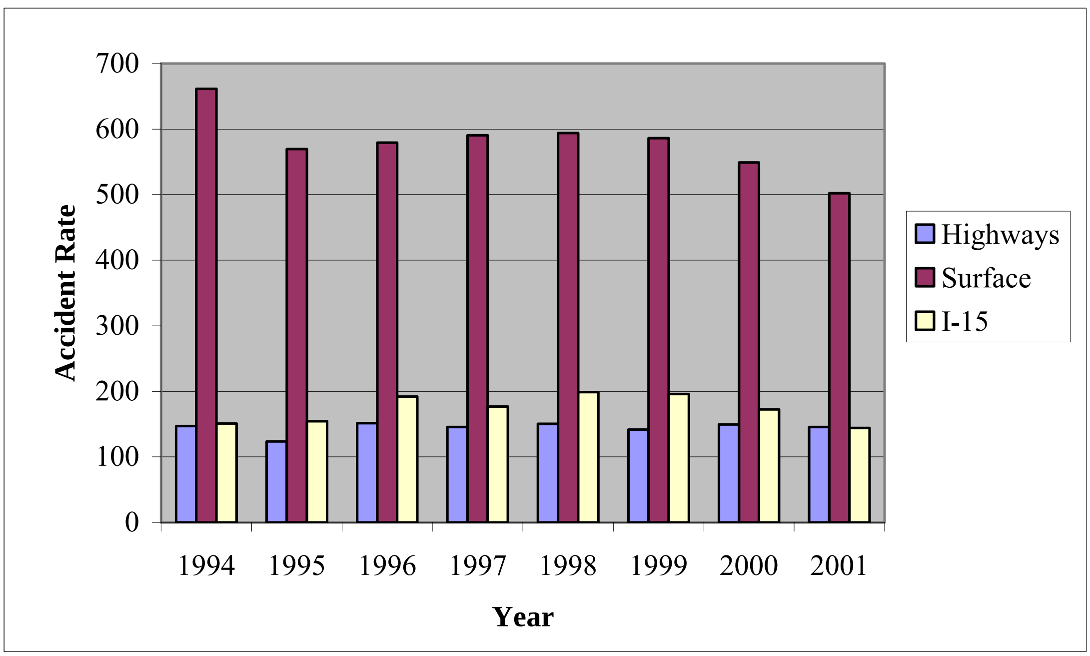


Figure 10.9: Number of Accidents on road types per 100 Million VMT

Accidents in work zones affect traffic. Figure 10.10 shows the number of accidents on I-15 in work zones from 1994 to 2001. These numbers increased 50 times between 1996 and 1997. The number of accidents per year varied according to the extent of the construction performed.

Figure 10.11 shows that the number of fatal accidents in work zones increased during reconstruction. Four fatal accidents occurred due to work zones. Reconstruction also caused an increase in accidents involving more than two vehicles.

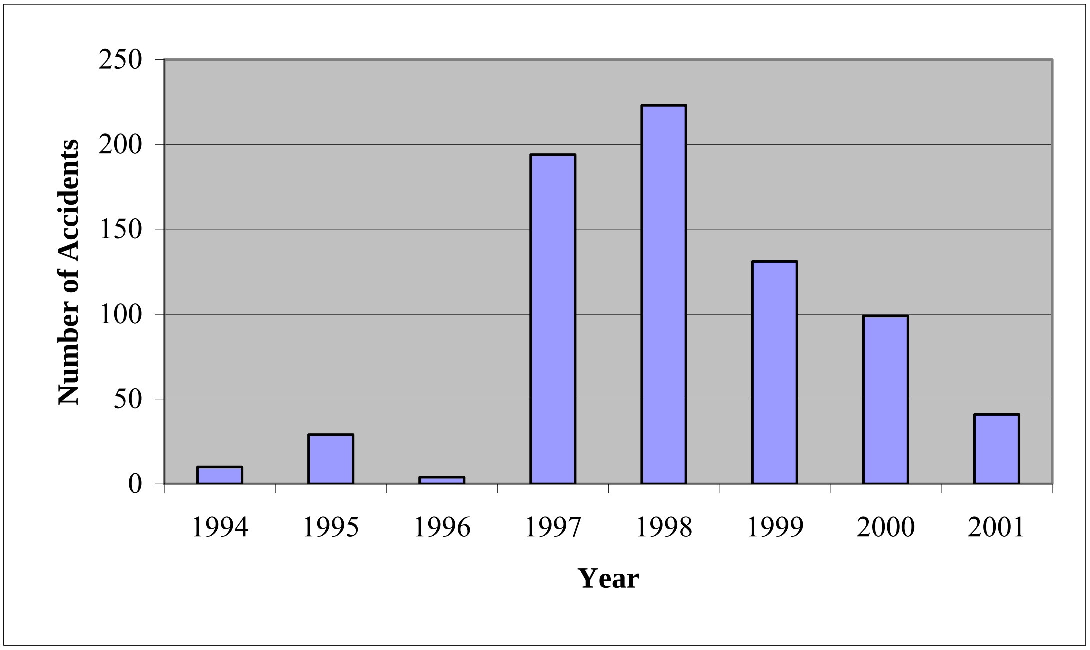


Figure 10.10: Work Zones Accidents During I-15 Reconstruction, 1994-2001

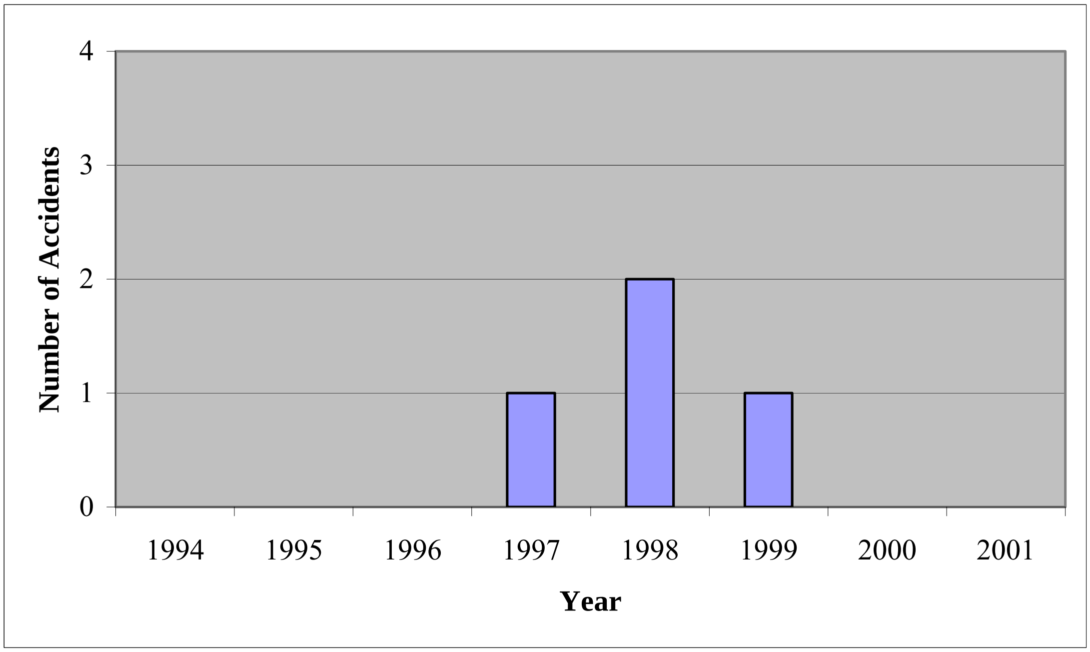


Figure 10.11: Fatal Accidents at Work Zones on I-15, 1994-2001

Figure 10.12 shows an increase in the number of accidents involving four, five, and six or more vehicles.

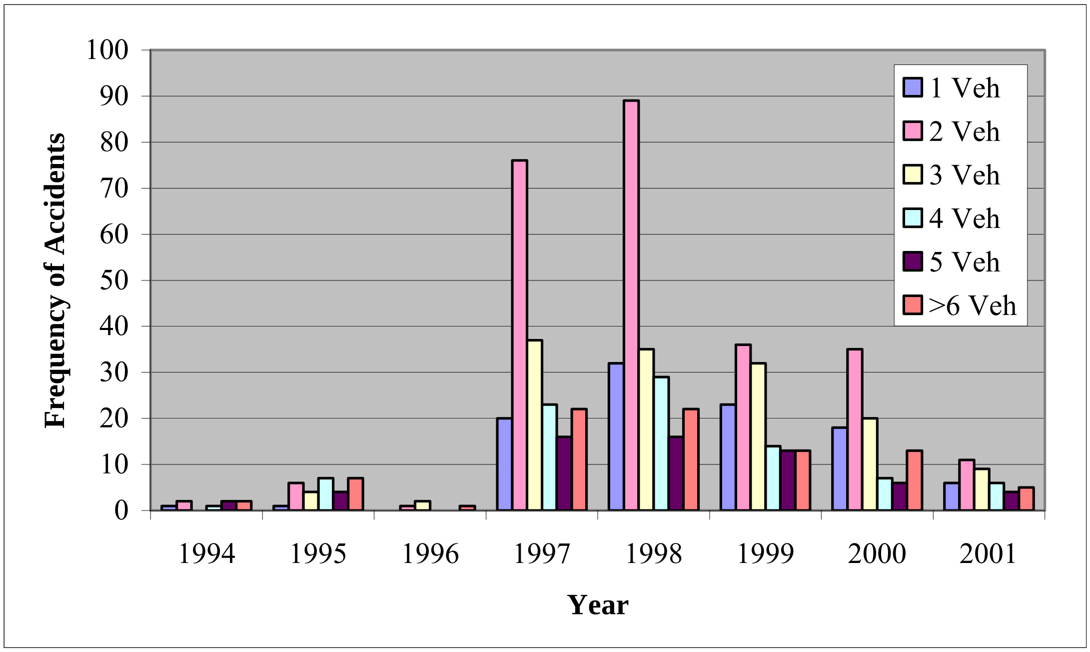


Figure 10.12: Multiple Vehicle Accidents at Work Zones on I-15, 1994-2001

10.5 Results

This section presents the number of accidents per DB, TB, and NB alternatives and the number of accidents per 100 million vehicle miles of travel that occurred in the Salt Lake County area and the major north-south routes examined in this study.

10.5.1 Salt Lake County Area

Figure 10.13 shows the number of accidents and VMT in Salt Lake County between 1994 and 2001. VMT has grown steadily by 2.6 percent per year between 1994 and 2001. Accident number has decreased steadily by 3.6 percent per year.

Figure 10.14 shows the relationship between accident number and million Vehicle Miles of Travel (MVMT). The linear relationship between the number of accidents and MVMT suggests that accident number decreases as MVMT increases. The decrease in accident number at a county level results from variables unrelated to the construction project. Variables that may influence accident number are safety programs, law enforcement, and alcohol related measures.

It was expected that VMT on I-15 would decrease during reconstruction. People may change their driving patterns and behavior during a reconstruction project. Some people will avoid making some trips and may change their normal mode of transportation to transit or carpool (Fuji 2001 [3]). However, in Salt Lake County VMT steadily increased over the reconstruction period.

It is unknown whether the I-15 DB reconstruction would cause an increase or a decrease in the number of accidents at a county level. Traffic accident statistics could be overshadowed by other traffic safety enforcement measures applied at approximately the same time. Therefore, the alternative that causes the lowest number of accidents on the county level cannot be concluded.

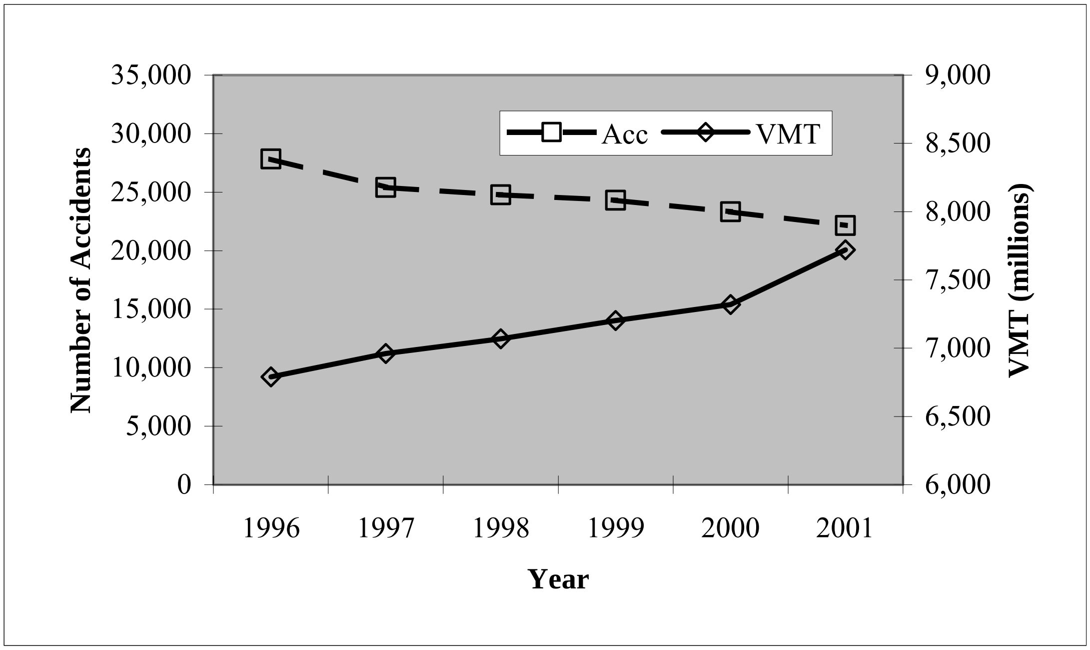


Figure 10.13: VMT and Number of Accidents in Salt Lake County

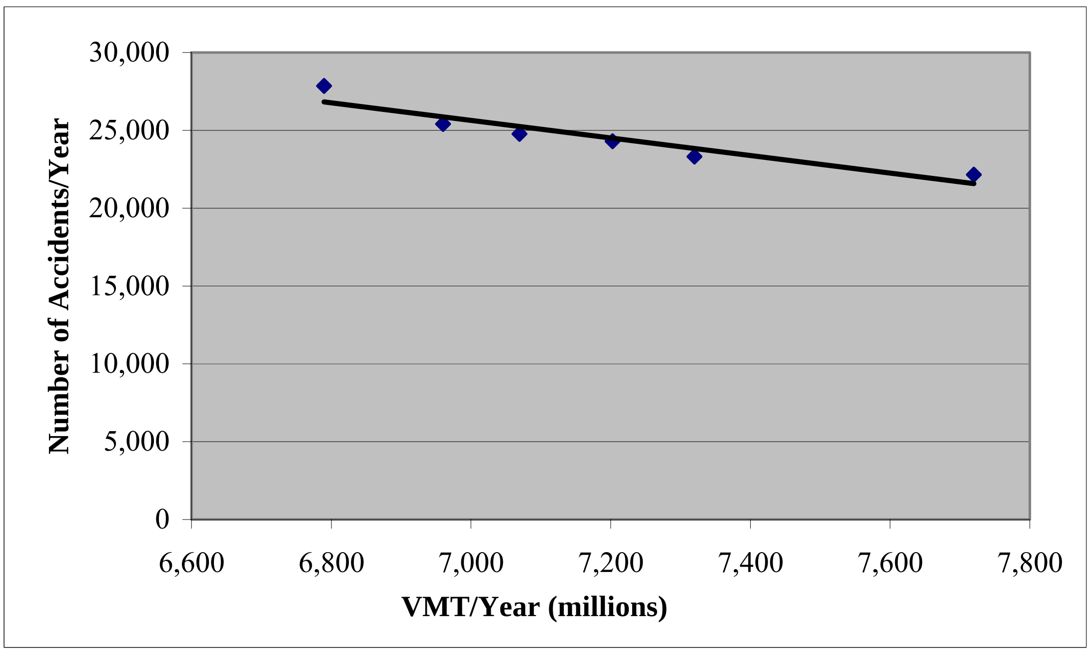


Figure 10.14: Number of Accidents vs. MVMT in Salt Lake County, 1996-2001

10.5.2 Major North-South Routes

Equation [7] is a regression model calibrated for highways. It was calibrated with I-15, I-215 West, I-215 East, and Bangerter Highway data from 1996 to 2001 (n=96).

$$\begin{array}{lll} \multicolumn{3}{l}{Number\ of\ \ Accidents\ \ per\ Season = 1.63 * MVMT} \\ \quad Standard\ Error & 0.04 & \\ \quad t\text{-}value & 38.4 & \quad [7] \\ \quad P\text{-}value & << 0.001 & \end{array}$$

The coefficient of determination (R^2) for this model is 0.83. Therefore, it explains 83% of the variation in the independent variable. Congestion, the number of interchanges open, and the length of the construction zone on I-15 were not significant variables at the 95% confidence level. Variables *Inter* and *Const* represent index for the number of interchanges open and the length of the construction zone. They had high correlations with MVMT. High correlation produces an unstable model. Therefore, calibration of a model with correlated variables is not recommended. In conclusion, the calibrated model is statistically significant and can be used to predict the number of accidents on freeways and highways.

Equation [5] is a regression model calibrated for surfaces streets. It was calibrated with data from State Street and Redwood Road (n=48). The model including 700 East data had a low coefficient of determination. Therefore, 700 East was removed from the analysis.

$$\begin{array}{lllll} \multicolumn{5}{l}{Number\ of\ \ Accidents = -381.2 + 9.8 * MVMT + 710 * Congestion} \\ Standar\ Error & 77.5 & 1.2 & 217.5 & \\ t\text{-}value & -4.9 & 8.0 & 3.2 & \quad [8] \\ P\text{-}value & << 0.001 & << 0.001 & 0.002 & \end{array}$$

Variables for the number of interchanges open and the length of construction were not significant at a 95% confidence level. The coefficient of determination for this model is 0.67. Although the model seems to have low explanatory power it can still be used to determine the number of accidents on surface streets.

Equations 7 and 8 were used to estimate traffic accident numbers for DB, TB, and NB. Figure 10.15 displays the combined accident rate for highways and surface streets for each reconstruction alternative. It shows that the NB alternative would maintain approximately the same accident rate during reconstruction. The rate increases steadily after 2002 as a result of higher traffic demand and increased congestion.

The DB alternative has the highest accident rate during reconstruction. When reconstruction is completed in 2001 the accident rate decreases until 2003. This decrease happens as diverted traffic returns from surface streets to I-15. After 2003 the accident rate increases steadily with higher traffic demand.

With the TB alternative, accident rate increases throughout reconstruction. The peaks and valleys displayed in Figure 5 show the influence of partial reconstruction projects on accident rate. After 2007 all traffic variables, including accident rate, are the same for the DB and TB alternatives.

Figure 10.16 shows the total number of accidents for DB, TB, and NB between 1996 and 2010. TB causes the highest number of accidents at 69,700. This is 6.7% higher than accident number with DB. TB's high accident rate is mainly due to its extended period of construction. As construction generates an increase in traffic on surface streets it enhances the probability of accidents. The NB alternative follows the TB alternative with the second highest number of accidents. This is due to increased congestion with NB. Overall, the DB alternative had the lowest number of accidents over the study period.

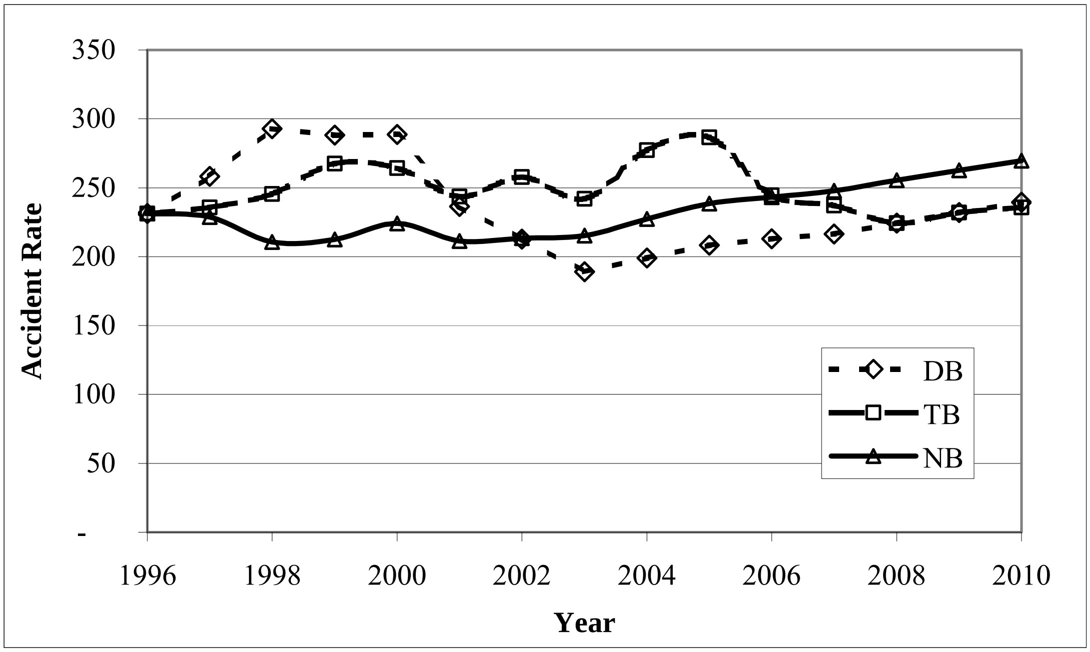


Figure 10.15: Accident Rate on Highways and Surface Streets

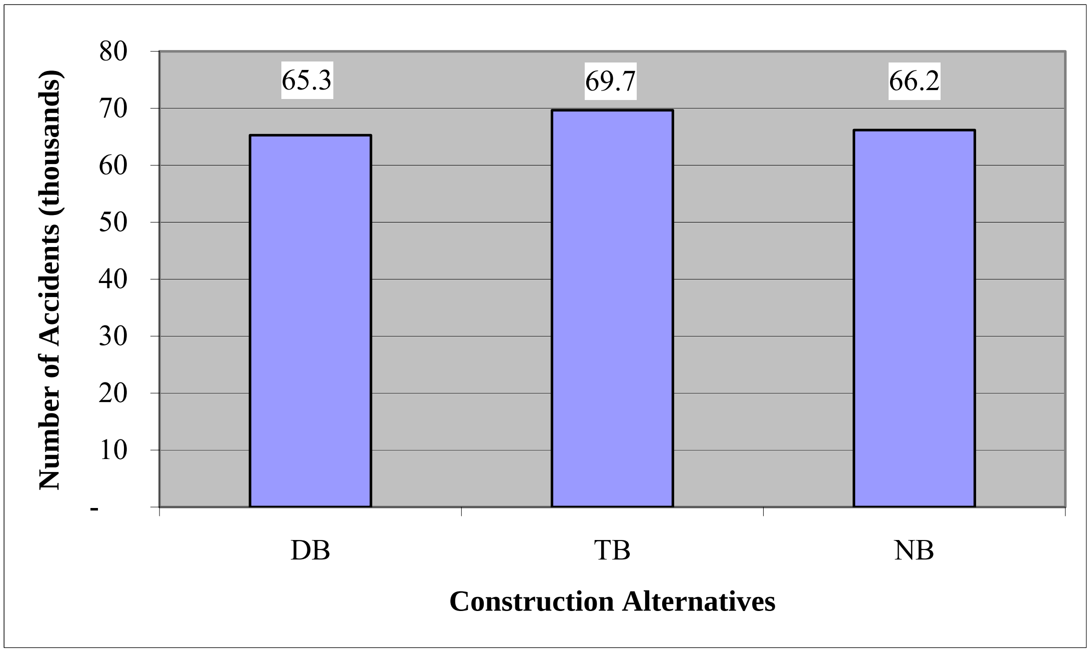


Figure 10.16: Total Number of Accidents Between 1996-2010

Figure 10.17 shows the VMT for DB, TB, and NB between 1996 and 2010. The NB alternative has the highest VMT at over 28,243 million. This is 1.2% higher than the DB alternative. The DB and the TB alternatives have similar VMTs. All of the alternatives experience the same traffic demand between 1996 and 2010. Therefore, DB and TB alternatives are more efficient than NB alternative because they provide the same service with a lower VMT. DB alternative is most efficient in terms of VMT.

Figure 10.18 shows the accident rate for each of the alternatives between 1996 and 2010. The figure shows that the TB alternative has the highest accident rate. DB and NB alternative have similar accident rates. DB and NB have similar accident rates. However, NB has a high number of accidents with a high VMT, and DB has a low number of accidents with a low VMT. Therefore, the DB alternative is has a lower number of accidents.

10.6 Conclusions

This study did not find a specific relationship between DB reconstruction and accident number on I-15. Accident number and VMT both increased and decreased over the study period. However, DB had the lowest number of accidents among the three alternatives on the major corridors. The TB alternative had the highest number of accidents. DB was found safest based on accident rate. If the proportion of fatal (0.3%), injury (37.9%), and property-damage-only (61.7%) accidents from 1997 to 2000 were maintained over the study period, the annual savings of DB over TB would be one fatal accident, 98 injuries, and 159 property-damage-only accidents.

10.7 Recommendations

This study found DB to be safest of the three alternatives. It recommends that future projects build under a DB strategy. It also recommends that traffic be retained on highways rather than on surface streets. This would avoid increased VMT and accident rates on surface streets. This study recommends that future research focus on other traffic variables that can affect accident number, such as geometry, speed variation, and congestion at the accident scene. It is also recommends that the modeled data in this study be compared, in the future, with real data. This will provide valuable information about model performance.

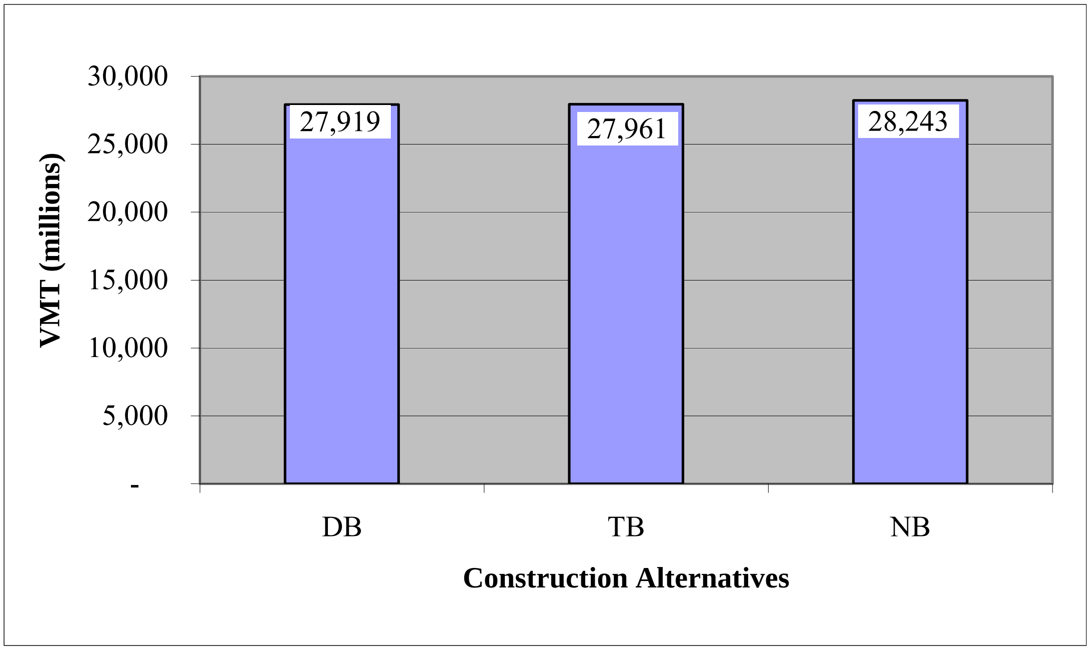


Figure 10.17: Total VMT Between 1996-2010

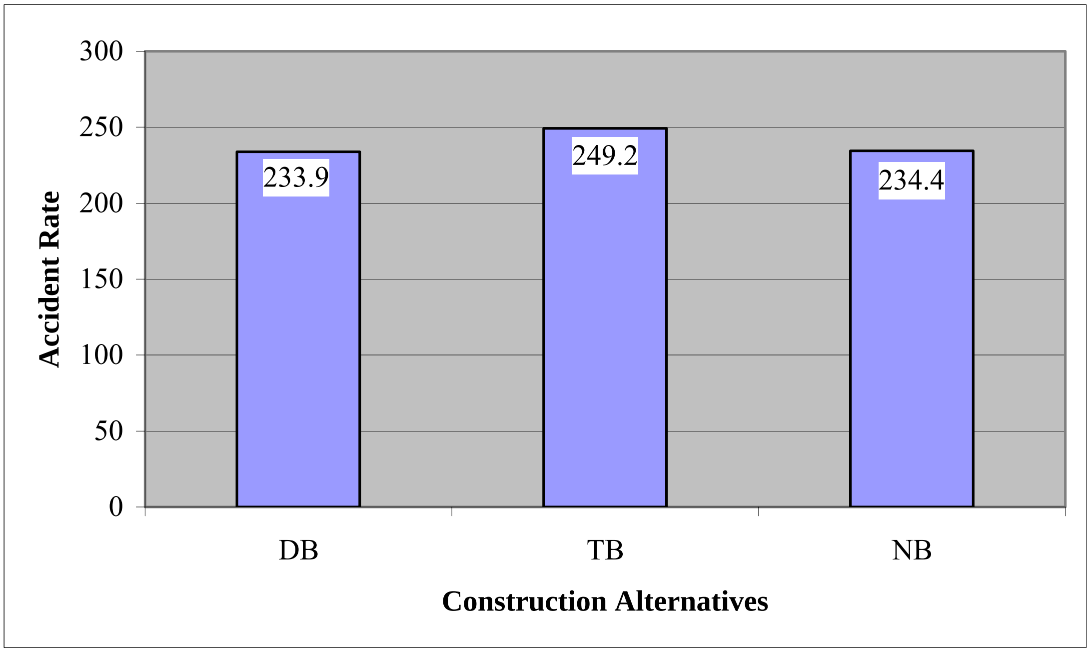


Figure 10.18: Accident Rate Between 1996-2010

11. EMISSION ANALYSIS

11.1 Introduction

Traffic congestion causes reduced vehicle speeds, delays, and frequent stops. These conditions cause increased fuel consumption and CO, NO_x, and VOC emissions. Reduced speeds and traffic delay also increase travel time. Consequently, vehicles remain on the road longer and emit more gases. Major freeway reconstruction also distracts drivers and sometimes produces significant traffic congestion. The existence and condition of alternative roads during reconstruction affects the whole traffic system. In addition, duration and intensity of construction influences congestion.

11.2 Research Objectives

This study compares CO, NO_x, and VOC emission levels for the DB, TB, and NB alternatives. It also investigates the impacts on accident number, accident rate, and emissions when traffic shifts from the freeway to arterial streets. The study models emission factors for the three criteria pollutants and inventories road network emissions.

11.3 Methodology

Mobile 6 is a software application program approved and recommended by the U.S Environmental Protection Agency (EPA). It is used to calculate emission factors for the three reconstruction alternatives. Mobile 6 estimates current and future emissions from highway motor vehicles. It is a well-calibrated and validated model and is widely accepted and used by state, local, and regional planning agencies. Mobile 6 provides default values (U.S. averages) for all potentially missing local data. Figure 11.1 shows a simplified process for finding emission inventories for DB, TB, and NB.

Local data inputs were used when possible to estimate emission levels for Salt Lake City. These data substituted for national averages. They came from the WFRC Mobile 6 emission model for Salt Lake City. The VISUM model provided all traffic inputs concerning road speeds and use in the Salt Lake County network. In addition, all meteorological, fuel, and vehicle and emission inspection data were taken from the WFRC Mobile 6 file to ensure that local traffic data represented real traffic conditions on the road network.

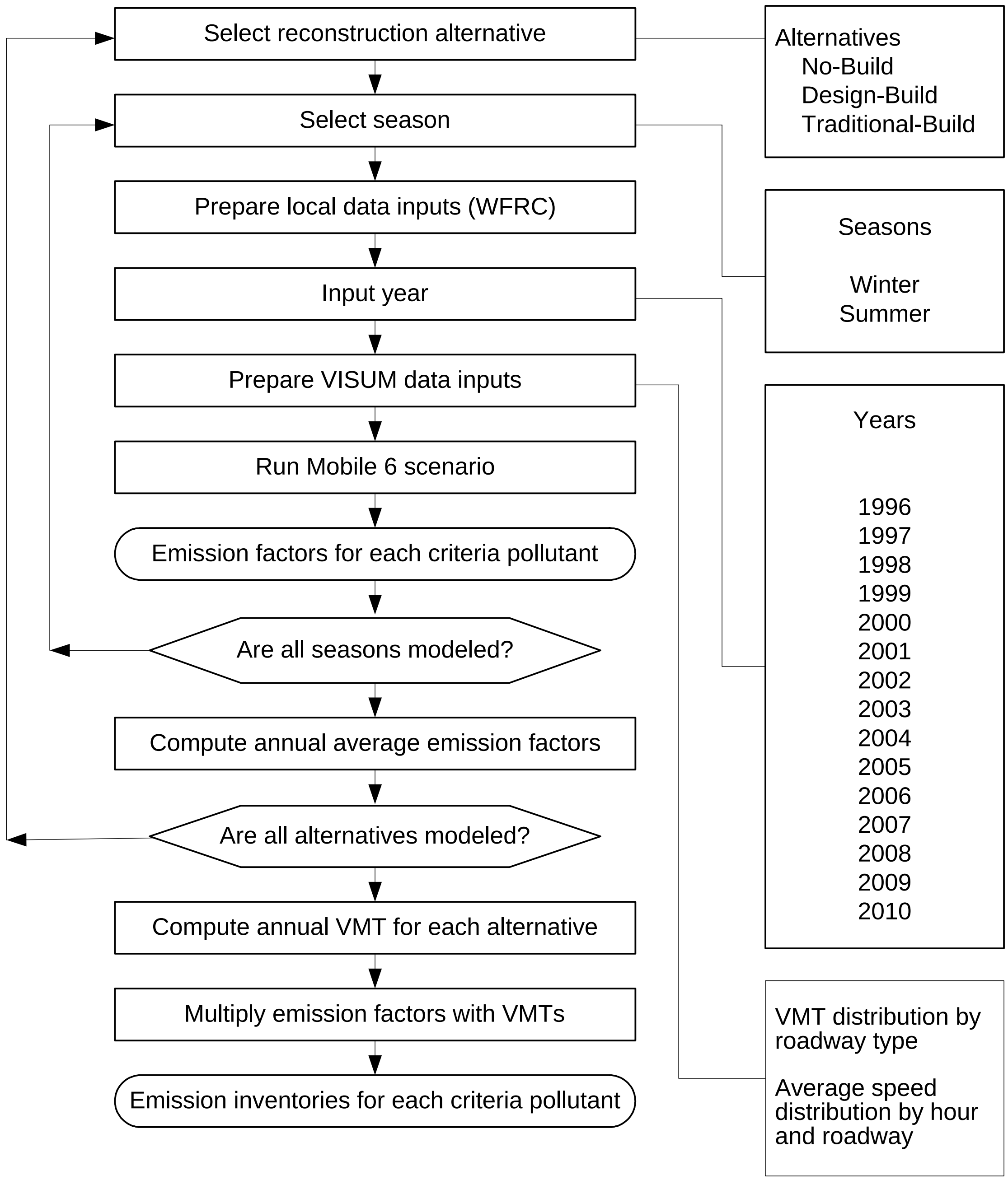


Figure 11.1: A procedure for modeling emissions for different reconstruction scenarios

11.4 Mobile 6 data inputs from the WFRC model

11.4.1 Vehicle Parameters

VMT Distribution by vehicle class
Registration distribution by vehicle class
Annual mileage accumulation by vehicle class

Engine start soak time distribution by hour
Engine starts per day and distribution by hour
Hot soak duration

11.4.2 Time Parameters

Calendar Year
Month
Weekday/Weekend

11.4.3 Fuel Parameters

Fuel characteristics
Diesel sales fractions by vehicle class and model year
Natural gas vehicle fractions

11.4.4 Meteorological Parameters

Daily Temperature Range
Altitude
Absolute Humidity
Cloud cover
Peak Sun & Sunrise/Sunset

11.4.5 Emission Inspection Parameters

Inspection/Maintenance program description
Anti-tampering inspection program description
Stage II refueling emission inspection program description

11.4.6 Traffic Parameters

Trip end distribution by hour
Average trip length distribution

11.5 Mobile 6 data inputs from the VISUM model

11.5.1 Traffic Parameters

VMT Distribution by roadway type
Average speed distribution by hour and roadway

11.6 Data Collection

Speed distribution data and VMT distribution data for DB, TB, and NB were taken from VISUM output files. Speed distribution data reflects traffic congestion on a route. It was collected for freeways and arterials at different time periods throughout the day. It was then used to determine average speeds for freeway and arterial links and to calculate emission levels.
Table 11.1 shows TB speed distribution for a representative day in 1996. Speed distribution was obtained for each diurnal period by filtering average speeds on links for two road classes (highways and arterials).

Table 11.1 Distribution of speeds for two road classes during different diurnal periods for Traditional-Build scenario

1996

Freeway

	2.5	5	10	15	20	25	30	35	40	45	50	55	60	65
AM	0.0000	0.0000	0.0000	0.0044	0.0015	0.0073	0.0103	0.0191	0.0191	0.0162	0.2937	0.0294	0.0617	0.5374
MD	0.0000	0.0000	0.0015	0.0000	0.0015	0.0029	0.0015	0.0000	0.0191	0.0206	0.2863	0.0103	0.0426	0.6138
PM	0.0000	0.0000	0.0029	0.0073	0.0073	0.0176	0.0411	0.0426	0.0441	0.0734	0.2893	0.0573	0.0881	0.3289
PEV	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.2952	0.0000	0.0000	0.7048
NEV	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.2952	0.0000	0.0000	0.7048

All roads

AM	0.0000	0.0005	0.0036	0.0130	0.1462	0.3596	0.3155	0.1089	0.0216	0.0066	0.0036	0.0000	0.0209	0.0000
MD	0.0000	0.0000	0.0000	0.0043	0.1303	0.3651	0.3276	0.1128	0.0275	0.0073	0.0043	0.0000	0.0209	0.0000
PM	0.0000	0.0000	0.0073	0.0352	0.2028	0.3846	0.2596	0.0691	0.0164	0.0043	0.0011	0.0039	0.0157	0.0000
PEV	0.0000	0.0000	0.0000	0.0000	0.1173	0.3194	0.3428	0.1557	0.0282	0.0114	0.0043	0.0000	0.0209	0.0000
NEV	0.0000	0.0000	0.0000	0.0000	0.1173	0.3194	0.3428	0.1557	0.0282	0.0114	0.0043	0.0000	0.0209	0.0000

The Mobile 6 model recognizes a difference in the amount of emissions produced based on the type of road facility used. For example, ten-thousand cars traveling 50 mph on the freeway emit less of one criteria pollutant than the same volume of vehicles traveling 35 mph on arterial streets. Table 11.2 shows percentages of VMT on different road classes during different diurnal periods.
Emission factors for the three criteria pollutants were obtained from the Mobile 6 model. They were then multiplied by the relevant VMTs for each alternative and year of the study. VMTs were also obtained from the VISUM output files. Table 11.3 shows VMT for the three reconstruction alternatives between 1996 and 2010.

Table 11.2: Percentage of VMT by the road class and time of day for T-B scenario

1997 Spring-Summer

	Freeway	Ramp	Arterial	Local	Total
AM	0.4226	0.0233	0.4524	0.1018	1.0000
MD	0.4313	0.0256	0.4407	0.1024	1.0000
PM	0.4201	0.0207	0.4521	0.1070	1.0000
PEV	0.4905	0.0244	0.3983	0.0869	1.0000
NEV	0.4973	0.0228	0.3912	0.0887	1.0000

Table 11.3: VISUM outputs for VMT for three reconstruction alternatives

VMT	NB	DB	TB
1996	6847752768	6847752768	6847752768
1997	6720899245	6724600228	6790888486
1998	6716737535	6711178210	6748556808
1999	6974477882	6974220262	6993185665
2000	6959752050	6977387534	6973585848
2001	6962578018	6976437718	6972951006
2002	7051091044	7063220780	7060861567
2003	7051091044	7063220780	7044780847
2004	7676360053	7688283145	7667104639
2005	7676360053	7688283145	7685432681
2006	7937404443	7950365289	7946041133
2007	7937404443	7950365289	7939749470
2008	7937404443	7950365289	7950365289
2009	9733040868	8751151982	8751151982
2010	9733040868	8751151982	8751151982

11.7 Results

Emission factors for VOC, NO_x, and CO were obtained after multiple runs of the Mobile 6 model. Tables 11.4, 11.5, and 11.6 show the emission coefficients for all reconstruction alternatives. The criteria pollution coefficients for each alternative were multiplied by relevant VMT for each year. Figures 11.2, 11.3, and 11.4 show the total VOC, CO and NOx emissions for DB, TB, and NB from 1996 to 2010.

Table 11.4: Emission coefficients for No-Build alternative

	VOC		CO		NOx	
Year	Summer	Winter	Summer	Winter	Summer	Winter
1996	1.879	1.734	22.795	31.776	2.729	3.095
1997	1.764	1.618	21.155	29.747	2.664	3.000
1998	1.651	1.505	19.994	28.102	2.576	2.862
1999	1.565	1.425	18.913	26.624	2.517	2.778
2000	1.502	1.371	18.205	25.456	2.439	2.689
2001	1.436	1.315	17.558	24.571	2.350	2.608
2002	1.345	1.236	17.233	24.406	2.253	2.490
2003	1.229	1.137	16.316	23.889	2.155	2.389
2004	1.092	1.012	14.336	22.033	1.971	2.182
2005	0.984	0.907	13.120	20.897	1.836	2.028
2006	0.913	0.842	12.772	20.660	1.709	1.892
2007	0.820	0.741	10.591	17.526	1.496	1.651
2008	0.727	0.648	9.142	15.576	1.307	1.443
2009	0.673	0.597	8.540	14.808	1.172	1.293
2010	0.613	0.545	8.062	14.098	1.055	1.164

Table 11.5: Emission coefficients for Design-Build alternative

	VOC		CO		NOx	
Year	Summer	Winter	Summer	Winter	Summer	Winter
1996	1.879	1.734	22.795	31.776	2.729	3.095
1997	1.783	1.631	21.027	29.619	2.673	3.006
1998	1.68	1.524	19.771	27.898	2.578	2.86
1999	1.588	1.441	18.7	26.431	2.52	2.777
2000	1.525	1.387	17.998	25.267	2.443	2.689
2001	1.436	1.316	17.654	24.645	2.356	2.614
2002	1.335	1.237	17.407	24.478	2.286	2.497
2003	1.223	1.133	16.503	24.053	2.168	2.405
2004	1.086	1.008	14.491	22.175	1.984	2.197
2005	0.974	0.9	13.278	21.041	1.848	2.043
2006	0.905	0.836	12.92	20.801	1.721	1.906
2007	0.813	0.736	10.706	17.64	1.507	1.664
2008	0.72	0.643	9.237	15.674	1.317	1.454
2009	0.666	0.592	8.627	14.9	1.181	1.303
2010	0.607	0.541	8.142	14.186	1.063	1.173

Table 11.6: Emission coefficients for Traditional-Build alternative

	VOC		CO		NOx	
Year	Summer	Winter	Summer	Winter	Summer	Winter
1996	1.879	1.734	22.795	31.776	2.729	3.095
1997	1.76	1.616	21.166	29.753	2.666	3.001
1998	1.659	1.509	19.907	28.023	2.573	2.857
1999	1.58	1.436	18.801	26.533	2.517	2.775
2000	1.517	1.381	18.123	25.393	2.445	2.693
2001	1.445	1.322	17.492	24.524	2.353	2.609
2002	1.358	1.245	17.101	24.305	2.281	2.515
2003	1.237	1.143	16.241	23.831	2.159	2.392
2004	1.116	1.031	14.204	21.949	1.976	2.182
2005	0.998	0.917	13.011	20.803	1.836	2.026
2006	0.918	0.846	12.813	20.706	1.714	1.897
2007	0.818	0.74	10.663	17.6	1.504	1.66
2008	0.725	0.647	9.203	15.64	1.314	1.45
2009	0.685	0.607	8.527	14.816	1.165	1.285
2010	0.624	0.553	8.046	14.095	1.048	1.157

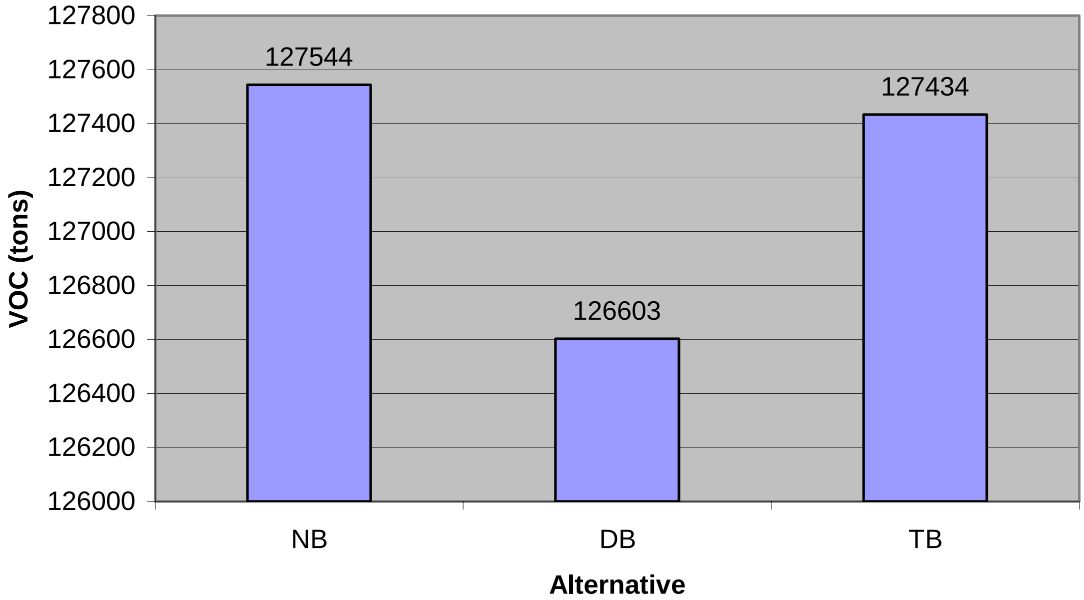


Figure 11.2: Total Volatile Organic Compounds (VOC) (1996-2010)

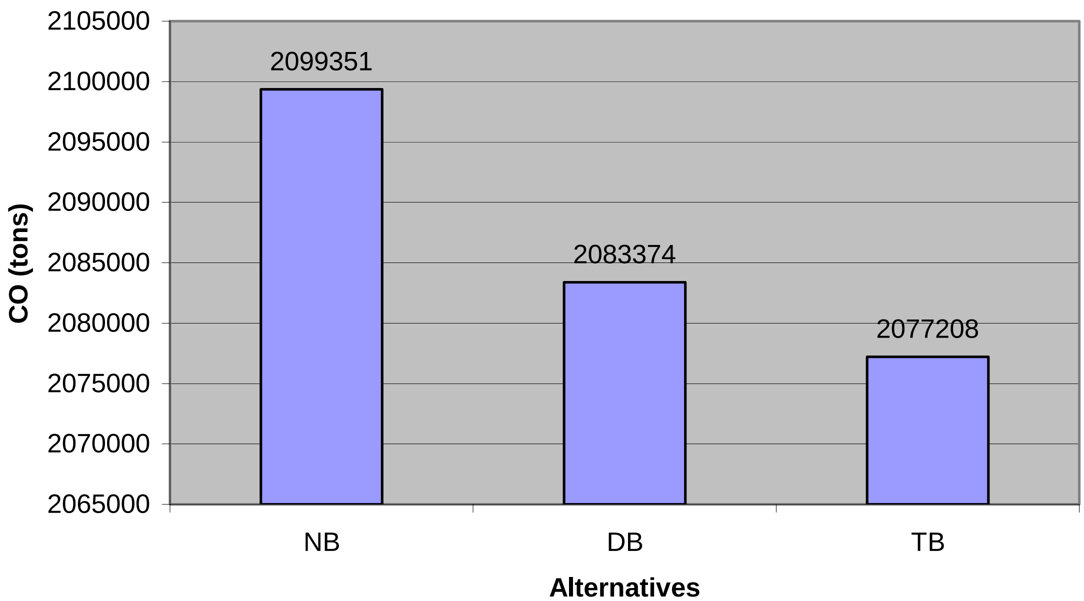


Figure 11.3: Total Carbon Monoxide (CO) (1996-2010)

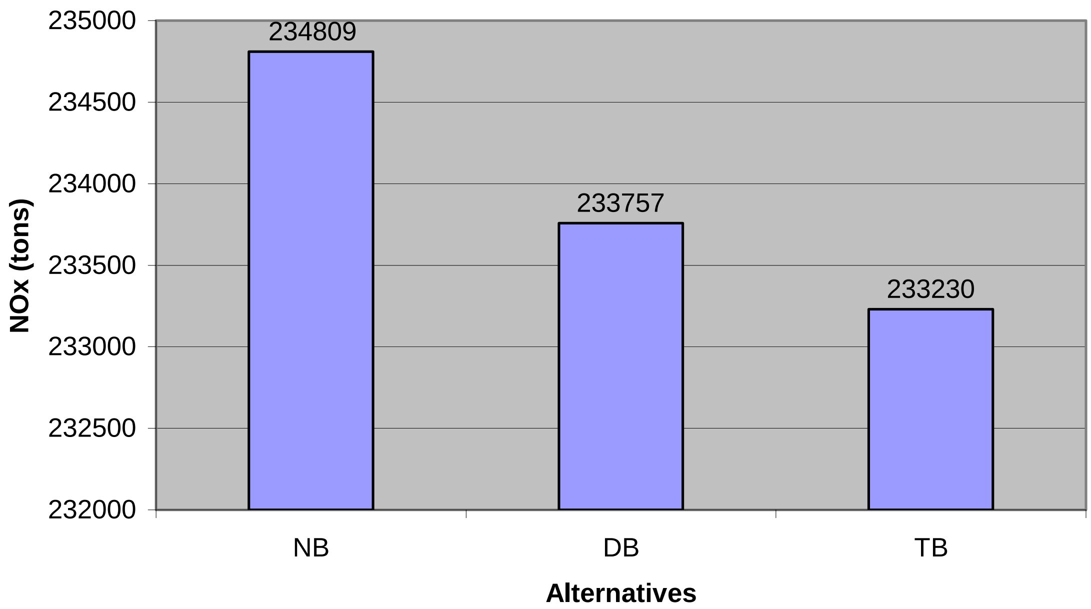


Figure 11.4: Total Nitrogen Oxides (NOx) (1996-2010)

11.8 Discussion

Higher levels of traffic congestion and the increased time that vehicles are on the road affect air quality.

11.8.1 VOC

This study measured the impact of DB, TB, and NB on vehicle emission levels in Salt Lake County. DB is the best reconstruction alternative in terms of VOC emissions. VOC emissions are approximately 800 tons lower for DB than for TB. VOC emissions for NB are slightly higher than for TB.

11.8.2 CO

CO emissions are lowest for TB. DB produces 5500 more tons of CO emissions than TB, but produces significantly less CO than NB.

Tang et al. *(7)* carried out a comprehensive study of Mobile 6 under various conditions. They changed the input parameters of the model one by one in order to observe how these changes impacted model output. They found that CO emissions increase when freeway traffic increases in comparison to arterial traffic. Vehicle speeds ranging from 30 to 35 mph cause the lowest CO emissions. Emissions increase for speeds lower than 30 mph or higher than 35 mph.

NB produces a high volume of CO emissions due to congested traffic conditions. These conditions result from overuse of non-reconstructed freeways and arterial streets. DB is associated with higher traffic speeds on re-constructed freeways. TB offers a more moderate reconstruction alternative. It takes longer than DB, but keeps partially closed freeways and arterial roads open. TB most closely matches the 30 to 35 mph speed range that produces the least amount of CO emissions.

11.8.3 NOx

As with CO emissions, TB also produces the lowest amount of NO_x emissions. DB produces about 530 more tons of NO_x than TB. NB produces the highest NO_x emissions. The lowest amount of NO_x is emitted when vehicles travel between 30 and 40 mph.

These NO_x emissions can be interpreted by Tang's study. They found that NO_x emissions increase when freeway traffic is greater than arterial traffic. With NB, freeways would be used to and beyond capacity throughout the study period. Congested traffic conditions reduce average link speeds. And, average speed drops below the 30 to 40 mph range on some arterial roads. These conditions increased NO_x emissions.

In contrast, DB produced the least congestion on the road network. It provided a higher level of service for users of the reconstructed I-15 and major arterial roads. This increased level of service meant higher average road speeds and increased NO_x emissions. Under DB, a higher percentage of freeway traffic versus arterial traffic also increased NO_x emissions. Highway traffic is higher for DB than for TB because TB users are restricted from a fully functional I-15 for a longer time period.

11.9 Conclusions

Two major conclusions can be drawn from the three-pollutant emission analysis for DB, TB, and NB. First, emission levels of all three pollutants are highest for NB. Second, emission results for DB are not consistent with its delay and accident savings. While DB is the best alternative for cutting delay and accident rates, it produces more NO_x and CO emissions than TB. However, DB does have the lowest level of VOC emissions. In spite of its higher emission levels, of the three alternatives DB provides the highest level of service to users.

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APPENDIX A

VISUM NETWORK FILE – AN EXTRACT

```
$VISION
$VERSION:VersNr;FileType;Language
2.80;Net;E
*
* ITC
* 11/13/02
*FileInfo
$INFO:TEXT
Beispielnetz Handbuch
M. Friedrich 20.7.95
*
$
* Scale and Time format
* Time specifications
* 00:06:30 -> 6 min 30 sec
* 00:06.30 -> 6 min 30 sec
* 06:30    -> 6 hours 30 min
* 06.30    -> 6 min 30 sec
* 6        -> 6 sec
$NETPARA:SCALE;LEFTHANDTRAFFIC;DECIMALPLACES
1.0000000;0;4
*
* Point of Interest (Definition)
        $POICATEGORYDEF:CATID;CODE;NAME;COMMENT;USE_IMAGEFILE;IMAGEFILE;USE_IMAGEHEIGHT;IMAGEHEIGHT
1;01;ATRS;Automatic Traffic Recorder Station;1;C:\Program Files\PTV_Vision\VISUM770\Example\Counter.WMF;0;7.00
2;02;Closures;Road or area closures;1;C:\Program Files\PTV_Vision\VISUM800\Example\Closed.bmp;1;6.00
3;03;Openings;Road or area openings;1;C:\Program Files\PTV_Vision\VISUM800\Example\Open.bmp;1;6.00
*
* List of user-defined attributes (Definition)
$USERATTDEF:AttID;CODE;NAME;COMMENT;OBJ_NAME;DATA_TYPE;MaxStrLen;DECIMALPLACES;COLSUMS;COLMEAN;COLMINMAX;VALUEMIN;VALUEMAX;VALUEDEFAULT
WS-RANK;WSTCH-RankLink;Wasatch Rank of Link;Wasatch Model - Rank of the link;LINK;INT;0;;0;0;0;;;0
WS-VOL;WSTCH-Volume;Wasatch Volume;Wasatch model assignment results for volumes for 24 hours;LINK;INT;0;;1;1;1;;;0
WS-SAT;WSTCH-Saturation;Wasatch Saturation;Wasatch model Volume/Capacity ratio;LINK;INT;0;;1;1;1;0;;0
WS-TCUR;WSTCH-TimeCurrent;Wasatch Current Travel Time;Wasatch model results for current travel time in seconds;LINK;INT;0;;1;1;1;;;0
WS-VCUR;WSTCH-CurrentSpeed;Wasatch Current Speed at the link;Wasatch model result for current speed;LINK;INT;0;;1;1;1;0;;0
WS-CAP;WSTCH-Cap1Hr1Ln;Wasatch Capacity/Hour/Lane;Wasatch model capacity per hour per lane;LINK;INT;0;;1;1;1;;;0
WS-ONEWAY;WSTCH-OneWay;Wasatch One Way;Wasatch Model One Way Indicator;LINK;INT;0;;0;0;0;0;1;0
SLC-DIRECT;SLC-Direction;Link Direction;Inbound and outboun directions of a link;LINK;STRING;10;;0;0;0;;;
```

```
*
* List of Transport Systems
* Transport system type specification:
* PR for PrT
* PU for PuT
* PW for PuT-WalkLink
* PC for PuT-Cargo
$TSYS:TSysCode;TSysName;TSysMode;TSys-v;PCU
P;Car;PR;200;1.000
L;HVeh;PR;100;2.000
*
* List of modes
*
$MODE:CODE;NAME;TSysCode
P;Car;P
L;HVeh;L
*
* List of demand segments
$DEMANDSEGMENT:CODE;NAME;MODE;OCCRATE
P;Car;P;1.000
L;HVeh;L;1.000
*
* List of node types 0-99
$NODETYPE:TYPE;NAME
*
* List of nodes
$NODE:Nr;CODE;NAME;TYPE;X-Coord;Y-Coord;STOP;TSysCode-PuT;MAINNODENR
1501;;;0;418942.0000;4563498.0000;0;;0
1502;;;0;418522.0000;4557497.0000;0;;0
1503;;;0;418950.0000;4563732.0000;0;;0
1504;;;0;422209.0000;4541476.0000;0;;0
1505;;;0;418962.0000;4564191.0000;0;;0
1506;;;0;418969.0000;4564424.0000;0;;0
1507;;;0;418972.0000;4564649.0000;0;;0
1508;;;0;417731.0000;4562098.0000;0;;0
……………………………………………
* Zonal Boundaries
$ZONEPOLY:Nr;INDEX;X-Coord;Y-Coord
*
* List of link types 0-99
$LINKTYPE:Nr;NAME;Cap-PrT;FAHRSTR;v0-PrT;vMin-PrT;TSysCode;vMax-PrT(P);vMax-
PrT(L);Rank
00;;99999;1;50;0;PL;200;100;1
01;Centroid;70000;1;32;0;PL;56;56;1
02;;99999;1;50;0;PL;200;100;1
03;;99999;1;50;0;PL;200;100;1
04;;99999;1;50;0;PL;200;100;1
05;;99999;1;50;0;PL;200;100;1
06;;99999;1;50;0;PL;200;100;1
07;;99999;1;50;0;PL;200;100;1
08;;99999;1;50;0;PL;200;100;1
```

09;;99999;1;50;0;PL;200;100;1
10;;99999;1;50;0;PL;200;100;1
11;Freeway - higher cap;2200;1;105;0;PL;129;129;1
12;Freeway - lower capa;1900;1;105;0;PL;129;129;1
13;Freeway - CD roads;1730;1;80;0;PL;105;105;1
14;Freeway - HOV lanes;2200;1;105;0;PL;129;129;3
15;Freeway - Rural/High;1900;1;121;0;PL;145;145;1
16;Freeway - off ramp;1900;1;64;0;PL;88;88;1
17;Freeway - off ramp l;1900;1;48;0;PL;72;72;1
18;Freeway - on ramp;1600;1;56;0;PL;80;80;1
19;Freeway - on ramp lo;1600;1;40;0;PL;64;64;1
20;Multilane Hwy;3460;1;80;0;PL;105;105;1
21;Principal arterial -;2280;1;37;0;PL;61;61;1
22;Principal arterial -;1340;1;35;0;PL;60;60;1
23;Principal arterial -;600;1;34;0;PL;58;58;1
24;Principal arterial -;2490;1;55;0;PL;79;79;2
25;Principal arterial -;1460;1;53;0;PL;77;77;2
26;Principal arterial -;670;1;50;0;PL;74;74;2
27;Principal arterial -;2700;1;66;0;PL;90;90;3
28;Principal arterial -;1600;1;64;0;PL;88;88;3
29;Principal arterial -;730;1;61;0;PL;85;85;3
30;;99999;1;50;0;PL;200;100;1
31;Minor arterial - Urb;2100;1;32;0;PL;56;56;1
32;Minor arterial - Urb;1200;1;31;0;PL;55;55;1
33;Minor arterial - Urb;530;1;29;0;PL;53;53;1
34;Minor arterial - Sub;2280;1;48;0;PL;72;72;2
35;Minor arterial - Sub;1340;1;47;0;PL;71;71;2
36;Minor arterial - Sub;600;1;43;0;PL;68;68;2
37;Minor arterial - Sub;2490;1;60;0;PL;84;84;3
…………………………………………………
* List of links
$LINK:Nr;FROMNODE;TONODE;TYPE;LENGTH;Cap-PrT;TSysCode;v0-PrT;ONEWAY;NUMLANES;NAME
2150;1501;1503;43;234;530;;26;1;1;Adams Ave
2150;1503;1501;43;234;530;;26;1;1;Adams Ave
2151;1501;2365;43;237;530;;26;1;1;Adams Ave
2151;2365;1501;43;237;530;;26;1;1;Adams Ave
2152;1502;1836;46;297;530;;40;1;1;5350 Sout
2152;1836;1502;46;297;530;;40;1;1;5350 Sout
2153;1502;2555;46;568;530;;40;1;1;5350 Sout
2153;2555;1502;46;568;530;;40;1;1;5350 Sout
2155;1503;2127;32;231;600;;31;1;2;24th St
2155;2127;1503;32;231;600;;31;1;2;24th St
2156;1503;2146;33;238;530;;29;1;1;24th St
2156;2146;1503;33;238;530;;29;1;1;24th St
2157;1503;2479;43;233;530;;26;1;1;Adams Ave
2157;2479;1503;43;233;530;;26;1;1;Adams Ave
2158;1504;1512;35;108;670;;47;1;2;Main St
2158;1512;1504;35;108;670;;47;1;2;Main St
2159;1504;1518;46;293;530;;40;1;1;Burton Ln
2159;1518;1504;46;293;530;;40;1;1;Burton Ln

```
2160;1504;1527;35;543;670;;47;1;2;Main St
2160;1527;1504;35;543;670;;47;1;2;Main St
2161;1505;1506;46;233;530;;40;1;1;Adams Ave
2161;1506;1505;46;233;530;;40;1;1;Adams Ave
2162;1505;2130;43;221;530;;26;1;1;22nd St
2162;2130;1505;43;221;530;;26;1;1;22nd St
2163;1505;2151;43;238;530;;26;1;1;22nd St
2163;2151;1505;43;238;530;;26;1;1;22nd St
…………………………………………………..
* List of link polygons
$LINKPOLY:FROMNODE;TONODE;INDEX;X-Coord;Y-Coord
*
* List of Major Flows
$MAJORFLOW:FROMNODE;VIANODE;TONODE
*
* List of standard values: Turning relations
*Types of turning relations    0   not used (standard value, if none specified)
*              1    to the right
*              2    straight
*              3    to the left
*              4    UTurn
* Attention: This time specification always in [sec]


$TURNINGSTANDARD:NODETYPE;TURNREL;TURNTYPE;t0-PrT;Cap-PrT;SYSCODE
??;??;?;0;99999;
1?;++;1;5;10000;
1?;++;2;0;10000;
1?;++;3;5;10000;
1?;+-;1;5;10000;
1?;+-;2;5;10000;
1?;+-;3;10;1000;
1?;-+;1;10;5000;
1?;-+;2;15;3000;
1?;-+;3;20;1000;
1?;--;1;15;5000;
1?;--;2;20;3000;
1?;--;3;30;1000;
*
* List of turning relations
$TURNINGRELATION:FROMNODE;VIANODE;TONODE;TSysCode;t0-PrT;Cap-PrT;TYPE
1501;1503;1501;;0;99999;4
1501;1503;2127;;0;99999;3
1501;1503;2146;;0;99999;1
1501;1503;2479;;0;99999;2
1503;1501;1503;;0;99999;4
1503;1501;2365;;0;99999;2
1501;2365;1501;;0;99999;4
1501;2365;2049;;0;99999;1
1501;2365;2071;;0;99999;3
1501;2365;2481;;0;99999;2
```

2365;1501;1503;;0;99999;2
2365;1501;2365;;0;99999;4
1502;1836;1502;;0;99999;4
……………………………..
* List of connectors
$CONNECTOR:ZONENR;NODENR;Direction;TYPE;LENGTH;PrT-Mode;PuT-Mode;t0-PrT;t-PuT;PERC(PR);PERC(PU)
400;3409;O;1;2014;0;0;227;0;;
400;3409;D;1;2014;1;0;227;0;;
400;3609;OD;1;812;1;0;91;0;;
400;4540;O;1;2046;1;0;230;0;;
400;4540;D;1;2046;0;0;230;0;;
400;10365;O;0;2041;1;0;1;1837;;
400;10365;D;0;2041;0;0;1;1837;;
400;10366;O;0;1874;0;0;1;1687;;
…………………………………
* List of areas
$AREA:Nr;NAME;CODE;TYPE;X-Coord;Y-Coord
1;Salt Lake City;Salt Lak;0;422398.2203;4514019.6407
2;West Valley City;West Val;0;414829.6657;4503387.3271
3;South Salt Lake;South Sa;0;424044.6070;4506334.8868
4;Taylorsville;Taylorsv;0;420004.4043;4500880.8193
5;Murray;Murray;0;424200.7549;4500646.7508
6;West Valley City;West Val;0;413329.4061;4500379.4280
7;West Jordan;West Jor;0;415759.7650;4494975.1076
8;Midvale;Midvale;0;424896.6348;4495868.6680
9;Sandy;Sandy;0;428179.2226;4491453.5919
10;Alta;Alta;0;447091.6837;4492095.9598
11;South Jordan;South Jo;0;416819.2705;4490059.8427
12;Draper;Draper;0;426822.3749;4483262.8631
13;Riverton;Riverton;0;417958.8387;4485378.6820
14;Herriman;Herriman;0;413525.8970;4483190.7732
15;Bluffdale;Bluffdal;0;419440.0813;4479908.4195
16;Holladay;Holladay;0;431124.0423;4500307.8315
*
* Polygons of areas
$AREAPOLY:Nr;INDEX;X-Coord;Y-Coord
1;1;420523.3340;4517765.9525
1;2;420627.8716;4517718.0411
1;3;420625.1996;4517413.6921
1;4;420835.5543;4517406.5611
1;5;420835.9684;4517510.7451
1;6;420844.4991;4517661.5764
1;7;420774.3523;4517741.9085
1;8;420738.4535;4517817.0335
1;9;420722.7447;4517853.4595
1;10;420747.8869;4517880.5646
1;11;420748.0186;4517903.2636
1;12;420732.2951;4517930.6059
1;13;420691.6666;4517971.7088
1;14;420601.8079;4518140.2500

1;15;420595.2674;4518187.9726
1;16;420627.3983;4518244.5543
1;17;420650.6375;4518337.5034
1;18;420648.8386;4518414.7156
1;19;420617.6830;4518526.1477
1;20;420570.7251;4518651.3066
1;21;420553.5469;4518821.6919
1;22;420583.4454;4518887.3702
………………………………….

* Point of Interest
$POI:Nr;CATID;CODE;NAME;COMMENT;X-Coord;Y-Coord;USE_IMAGEFILE;IMAGEFILE;USE_IMAGEHEIGHT;IMAGEHEIGHT
1;1;501;I-215;2500 North;420204.0875;4519819.0729;1;C:\Program Files\PTV_Vision\VISUM770\Example\Counter.WMF;1;7.00
2;1;407;SR-68;Redwood Road South of Bluffdale;419942.7317;4479796.8317;1;C:\Program Files\PTV_Vision\VISUM770\Example\Counter.WMF;1;7.00
3;1;302;I-15;South of Draper Crossroads;424580.3258;4485466.3203;1;C:\Program Files\PTV_Vision\VISUM770\Example\Counter.WMF;1;7.00
4;1;409;SR-186;North Temple at Jordan River Bridge;421721.8598;4513588.4066;1;C:\Program Files\PTV_Vision\VISUM770\Example\Counter.WMF;1;7.00
5;1;408;SR-68;Redwood Road North of 1700 South;420772.9915;4509769.2114;1;C:\Program Files\PTV_Vision\VISUM770\Example\Counter.WMF;1;7.00
6;1;340;I-80;1100 West Overpass;422030.2421;4512864.8945;1;C:\Program Files\PTV_Vision\VISUM770\Example\Counter.WMF;1;7.00
7;1;356;SR-201;2100 South West of Jordan River Bridge;421698.1381;4508345.9089;1;C:\Program Files\PTV_Vision\VISUM770\Example\Counter.WMF;1;7.00
8;1;353;I-15;North of 3100 South Overpass;419503.8800;4506566.7807;1;C:\Program Files\PTV_Vision\VISUM770\Example\Counter.WMF;1;7.00
9;1;354;SR-171;3300 South West of 900 West SLC;421567.6687;4505546.7472;1;C:\Program Files\PTV_Vision\VISUM770\Example\Counter.WMF;1;7.00
10;1;355;SR-171;7658 West 3500 South SLC;408983.3020;4505439.9995;1;C:\Program Files\PTV_Vision\VISUM770\Example\Counter.WMF;1;7.00
11;1;351;I-215;West of 700 West Overpass;422243.7375;4498774.1992;1;C:\Program Files\PTV_Vision\VISUM770\Example\Counter.WMF;1;7.00
12;1;345;SR-269;500 South On Ramp WB;423453.5446;4512117.6606;1;C:\Program Files\PTV_Vision\VISUM770\Example\Counter.WMF;1;7.00
13;1;346;SR-269;600 South Off Ramp EB;423726.3443;4511892.3044;1;C:\Program Files\PTV_Vision\VISUM770\Example\Counter.WMF;1;7.00
14;1;325;SR-89;1087 South State Street SLC;425078.4817;4510729.9406;1;C:\Program Files\PTV_Vision\VISUM770\Example\Counter.WMF;1;7.00
……………………………………………………………………………..
* Point of Interest (Linkages)
$LINKTOPOI:FROMNODE;TONODE;RELPOS;POIID;CATID
*
* Point of Interest (Linkages)
$NODETOPOI:NODENR;POIID;CATID
*
* List of user-defined attributes: Point of Interest
$POI_USERATT:Nr;CATID;AttID;VALUE
*

* List of user-defined attributes: Links
$LINK_USERATT:FROMNODE;TONODE;AttID;VALUE
1501;1503;WS-RANK;4
1503;1501;WS-RANK;4
1501;2365;WS-RANK;4
2365;1501;WS-RANK;4
1502;1836;WS-RANK;4
1836;1502;WS-RANK;4
1502;2555;WS-RANK;4
2555;1502;WS-RANK;4
1503;2127;WS-RANK;3
2127;1503;WS-RANK;3
1503;2146;WS-RANK;3
2146;1503;WS-RANK;3
1503;2479;WS-RANK;4
2479;1503;WS-RANK;4
1504;1512;WS-RANK;3
1512;1504;WS-RANK;3
1504;1518;WS-RANK;4
1518;1504;WS-RANK;4
1504;1527;WS-RANK;3
1527;1504;WS-RANK;3
1505;1506;WS-RANK;4
1506;1505;WS-RANK;4
1505;2130;WS-RANK;4
2130;1505;WS-RANK;4
1505;2151;WS-RANK;4
2151;1505;WS-RANK;4
1505;2479;WS-RANK;4
2479;1505;WS-RANK;4
1506;1507;WS-RANK;4
1507;1506;WS-RANK;4
1506;2139;WS-RANK;4
…………………………..

APPENDIX B
VISUM LINK ATTRIBUTES FILE – AN EXAMPLE

$VISION

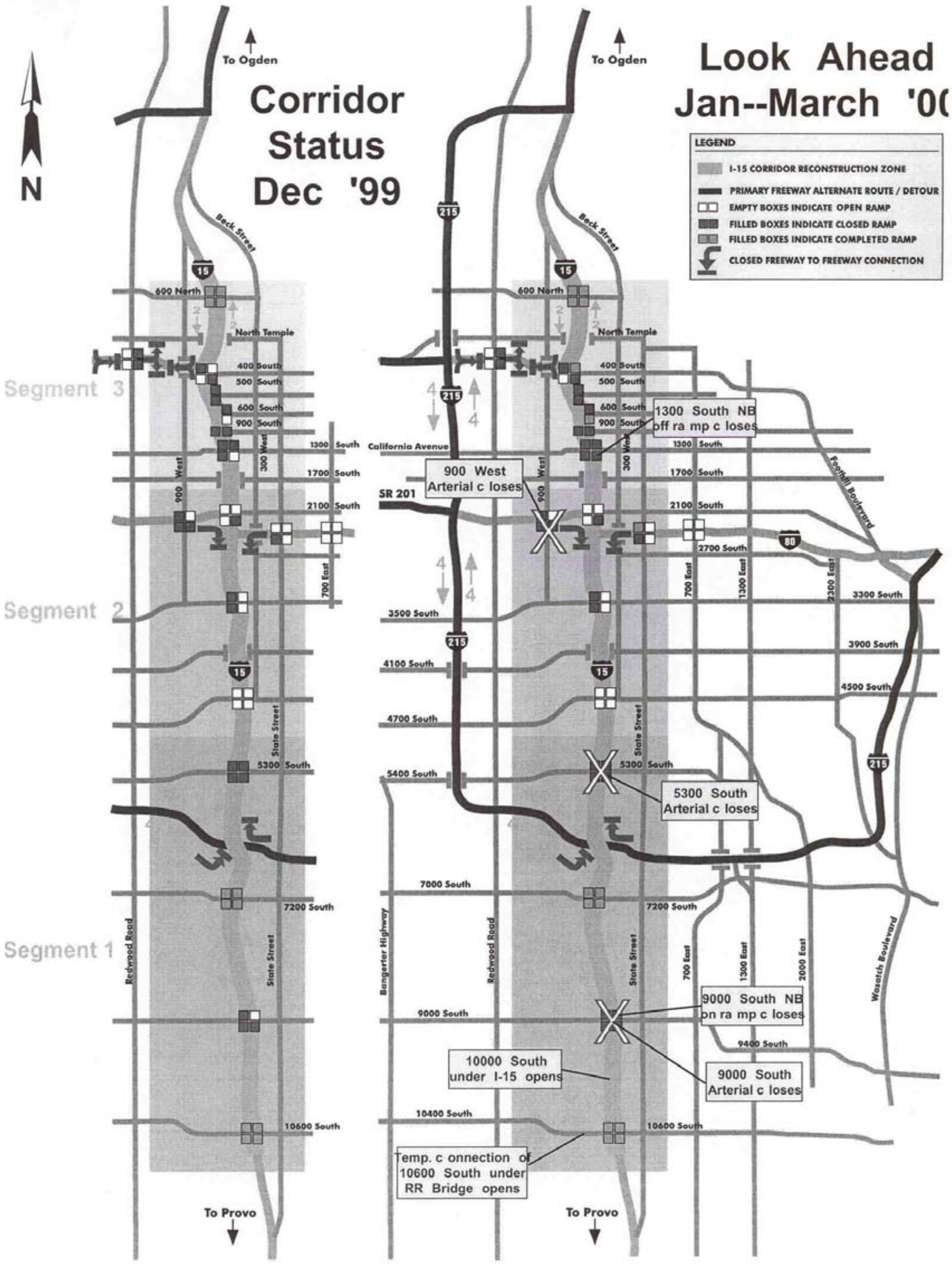
$VERSION:VersNr;FileType;Language
1.0;Att;E

$+LINK: Nr	FROMNODE	TONODE	NAME	TYPE	LENGTH	Cap-PrT	VolPers-PrT	
3641	2085	4611	3900 South	35	240	4020	4704	……..
3641	4611	2085	3900 South	35	240	4020	4534	……..
3642	2085	4613	3900 South	35	240	4020	4534	……..
3642	4613	2085	3900 South	35	240	4020	4704	……..
3805	2153	4923	5300 South	34	299	6840	5921	……..
3805	4923	2153	5300 South	34	299	6840	5416	……..
3806	2153	5457	5300 South	34	261	6840	5416	……..
3806	5457	2153	5300 South	34	261	6840	5921	……..
3824	2159	4901	7200 Sout	35	296	4020	3401	……..
3824	4901	2159	7200 Sout	35	296	4020	4850	……..
3825	2159	5041	7200 Sout	35	333	4020	4850	……..
3825	5041	2159	7200 Sout	35	333	4020	3401	……..
4197	2301	5364	400 West	42	241	3600	89	……..
4197	5364	2301	400 West	42	241	3600	265	……..
4198	2301	5470	400 West	42	239	3600	265	……..
4198	5470	2301	400 West	42	239	3600	89	……..
4296	2341	4916	Winchester St	46	185	1590	2098	……..
4296	4916	2341	Winchester St	46	185	1590	1834	……..
4297	2341	4917	Winchester St	46	584	1590	1834	……..
4297	4917	2341	Winchester St	46	584	1590	2098	……..
4460	2414	10268	CD Road	13	273	5190	2774	……..
4490	2429	4249	CD Road	13	269	5190	3064	……..
4647	2496	3629	North Temple St	35	773	4020	4390	……..
4647	3629	2496	North Temple St	35	773	4020	4174	……..
4648	2496	4861	North Temple St	35	352	4020	4174	……..
4648	4861	2496	North Temple St	35	352	4020	4390	……..
4787	2561	5034	Center St	35	378	4020	2596	……..
4787	5034	2561	Center St	35	378	4020	2189	……..
4788	2561	5035	Center St	35	155	4020	2189	……..
4788	5035	2561	Center St	35	155	4020	2596	……..
4823	2582	10263	CD Road	13	295	5190	1451	……..
4844	2598	4825	11400 Sou	36	206	1800	851	……..
4844	4825	2598	11400 Sou	36	206	1800	2302	……..
4845	2598	5273	11400 Sou	36	189	1800	2455	……..
4845	5273	2598	11400 Sou	36	189	1800	2439	……..
4846	2598	10346	I-15 NB o	18	235	4800	2164	……..
4851	2619	5566	3200 West	46	1172	1590	656	……..
4851	5566	2619	3200 West	46	1172	1590	603	……..
4852	2619	5568	3200 West	46	844	1590	603	……..
4852	5568	2619	3200 West	46	844	1590	656	……..
4885	3412	4034	South Campus Dr	35	602	4020	713	……..

4885	4034	3412	South Campus Dr	35	602	4020	998	……..
4886	3412	4564	South Campus Dr	35	279	4020	998	……..
4886	4564	3412	South Campus Dr	35	279	4020	713	……..
4888	3413	10189	CD Road	13	305	5190	3865	……..
4925	3428	3447	CD Road	13	317	15570	7410	……..
4936	3432	5013	Blank	16	238	11400	454	……..
4937	3433	5013	CD Road	13	187	10380	68	……..
4980	3447	3514	CD Road	13	932	15570	7410	……..
5035	3466	3515	CD Road	13	266	15570	7868	……..
5067	3477	10045	I-15 SB o	18	300	4800	0	……..
5093	3485	3511	I-15 SB o	16	72	5700	0	……..
5128	3497	3546	I-15 NB o	16	238	5700	2	……..
5138	3501	10042	I-15 NB o	18	201	4800	0	……..
5142	3503	3610	2100 Nort	34	1193	6840	1197	……..
5142	3610	3503	2100 Nort	34	1193	6840	1580	……..
5143	3503	3611	2100 Nort	34	233	6840	1544	……..
5143	3611	3503	2100 Nort	34	233	6840	1163	……..
5144	3503	3663	2200 West	44	775	6300	36	……..
5144	3663	3503	2200 West	44	775	6300	34	……..
5145	3504	4630	Redwood R	36	428	1800	664	……..
5145	4630	3504	Redwood R	36	428	1800	715	……..
5146	3504	4835	1700 Nort	46	422	1590	36	……..
5146	4835	3504	1700 Nort	46	422	1590	38	……..
5147	3504	4846	Redwood R	36	446	1800	689	……..
5147	4846	3504	Redwood R	36	446	1800	636	……..
5148	3505	3507	2300 Nort	36	1403	1800	0	……..
5148	3507	3505	2300 Nort	36	1403	1800	2	……..
5149	3505	3609	Redwood R	36	1483	1800	532	……..
5149	3609	3505	Redwood R	36	1483	1800	408	……..
5150	3505	4846	Redwood R	36	796	1800	410	……..
5150	4846	3505	Redwood R	36	796	1800	532	……..
5153	3507	3511	I-15 SB 2	46	373	1590	0	……..
5153	3511	3507	I-15 SB 2	46	373	1590	0	……..
5154	3507	3553	I-15 NB 2	46	161	1590	0	……..
5154	3553	3507	I-15 NB 2	46	161	1590	2	……..
5166	3511	3477	I-15 SB o	18	161	4800	0	……..
5168	3513	3501	I-15 NB o	18	217	4800	0	……..
5169	3513	3553	I-15 NB 2	46	473	1590	2	……..
5169	3553	3513	I-15 NB 2	46	473	1590	0	……..
5170	3514	3466	CD Road	13	889	15570	7868	……..
………	……………	……….	………………..	….	……….	……...	……………….	……..
………	……………	……….	………………..	….	……….	……...	……………….	……..
………	……………	……….	………………..	….	……….	……...	……………….	……..

APPENDIX C

GRAPHICAL EXAMPLE OF THE UDOT CLOSURE SCHEDULES



Corridor Status Dec '99
Look Ahead Jan--March '0(
LEGEND
I-15 CORRIDOR RECONSTRUCTION ZONE
PRIMARY FREEWAY ALTERNATE ROUTE / DETOUR
EMPTY BOXES INDICATE OPEN RAMP
FILLED BOXES INDICATE CLOSED RAMP
FILLED BOXES INDICATE COMPLETED RAMP
CLOSED FREEWAY TO FREEWAY CONNECTION
To Ogden
To Provo
Segment 3
Segment 2
Segment 1
1300 South NB off ra mp c loses
900 West Arterial c loses
5300 South Arterial c loses
9000 South NB on ra mp c loses
10000 South under I-15 opens
9000 South Arterial c loses
Temp. c onnection of 10600 South under RR Bridge opens

APPENDIX D

WASATCH CONSTRUCTORS' CLOSING ACTIVITIES

Activity ID	Activity Description	Early Start	Early Finish	Actual Duration	1997 APR 31 7 14 21 28 / MAY 5 12 19 26 / JUN 2 9
48000.0	Traffic Close 600 N Off & On Ramps	07MAY97A	12MAY97A	2	Traffic Close 6
48010.0	Traffic Close 600 N @ 300 & 900 W	07MAY97A	12MAY97A	2	Traffic Close 6
48020.0	Traffic Close 800 W @ 500 & 700 N	07MAY97A	07MAY97A	1	Traffic Close 800
48005.0	Traffic Close 600N St Over I-15	08MAY97A	12MAY97A	3	Traffic Close 6
48030.0	Traffic Close 500 W @ 500 & 600 N	09JUN97A	09JUN97A	1	T
48040.0	Traffic Close 400 W @ 500 & 700 N	09JUN97A	09JUN97A	1	T
48050.0	Traffic Close Pugsley St @ 600 N	09JUN97A	09JUN97A	1	T
49000.0	Maintenance During Const. NTP thru June '98	13JUN97A	30JUN98A	267	
46060.0	Traffic Switch to SB M/L @ 31+300	20JUN97A	28JUN97A	6	
47110.0	Traffic Close I 80 W from 500 S & NB I-15	20JUN97A	28JUN97A	6	
47130.0	Traffic Switch I-15 NB to Exist SB 2/2	20JUN97A	28JUN97A	6	
47360.0	Traffic Close I-80 E to NB I-15	20JUN97A	28JUN97A	6	
41105.0	Strategic Closure 215 W to 15N Ramp	23JUN97A	23JUN97A	1	
46030.0	Traffic Close Ramp 1300S-A	28JUN97A	28JUN97A	0	
41115.0	Traffic Close 7200 to I-15S Ramp A	07JUL97A	07JUL97A	1	
41110.0	Traffic Close I-15S to 7200 Ramp C	17JUL97A	17JUL97A	1	
44010.0	Traffic Close Ramp 33B, 33D (Phase 1)	01AUG97A	01AUG97A	1	
42300.0	Traffic Switch to NB I-15 2+2	14AUG97A	14AUG97A	1	
43010.0	Traffic Close Ramp 45A & 45C (Phase 1)	15AUG97A	15AUG97A	1	
43126.0	Traffic 2+2 (NB 4500S, SB 3300S) (Phase 1)	15AUG97A	15AUG97A	1	
41300.0	Traffic Close 15N 215E	21AUG97A	21AUG97A	1	
45430.0	Traffic Close 80w15s / 80w15nc	27AUG97A	27AUG97A	1	
46050.0	Traffic Close EN-NBCD	28AUG97A	28AUG97A	1	
45000.0	Traffic Ph1 (NB 2400S, EB80)	29AUG97A	29AUG97A	1	
45005.0	Traffic Close 2100s Ramps/open temp ramps	29AUG97A	29AUG97A	1	
46040.0	Traffic Close Ramp 1300S-D	29AUG97A	29AUG97A	1	
46005.0	Traffic Close Ramp SBCD-1	02SEP97A	02SEP97A	1	
46010.0	Traffic Close Ramp SBCD-3	02SEP97A	02SEP97A	1	
40000.0	Traffic Switch to NB I-15 3/3 90th to 72nd	16SEP97A	25OCT97A	27	
40005.0	Traffic Switch to NB I-15 2/2 106th to 90th	16SEP97A	03OCT97A	14	
41100.0	Traffic Switch Belly 3/3	04OCT97A	04OCT97A	0	
40007.1	Traffic Close 106th SB On-Ramp (A)	06OCT97A	06OCT97A	1	
47300.0	Traffic Close 400 S	24OCT97A	10NOV97A	12	
40007.1	Traffic Close 106th SB Off-Ramp (C)	09NOV97A	09NOV97A	0	
46000.0	Traffic Close Ramp 1300S-C	05JAN98A	06JAN98A	2	
40007.0	Traffic Switch 106th to 1/1 Phase 1	09FEB98A	09FEB98A	1	
40130.0	Open Traffic Detour 106th to 108th	09FEB98A	09FEB98A	1	
45820.0	Traffic Switch WB 2+2	09MAR98A	23MAR98A	5	
47100.0	Traffic Close I-80E to SB I-15	10APR98A	10APR98A	1	
41210.0	Traffic Close 7200 S Arterial	04JUN98A	04JUN98A	1	
49010.0	Maintenance During Const. July '98 thru June '99	01JUL98A		765	
47210.0	Traffic Close I-80 W @ SB I-15	09AUG98A	09AUG98A	0	
12290.8	Detour 15N to 215W	13AUG98A	13AUG98A	1	
40007.2	Traffic Close 106th NB On-Ramp (D)	24AUG98A	24AUG98A	1	
40007.2	Traffic Close 106th NB Off-Ramp (B)	24AUG98A	24AUG98A	1	
48060.0	Traffic Switch Open 600 N & Other Ramps	01SEP98A	24OCT98A	36	
47120.0	Traffic Close 600 South	15SEP98A	24OCT98A	27	
40009.1	Traffic Open 106th SB On-Ramp (A)	09OCT98A	10OCT98A	1	
40020.0	Traffic Close Ramp 90-A	09OCT98A	10OCT98A	1	
41125.0	Traffic Switch to 2/2 on NB 72nd to 59th Ph 1	09OCT98A	10OCT98A	1	
41170.0	Traffic Open Ramp 7200 to I-15 S Ramp A	09OCT98A	10OCT98A	1	
41228.0	Detour 215 W to I-15 S	24OCT98A	24OCT98A	0	

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41215.0	Traffic Open 7200 S Arterial	30OCT98A	30OCT98A	1	
41120.0	Traffic Open Ramp 215 E to I-15S (Path F)	06NOV98A	09NOV98A	2	
41220.0	Traffic Switch to New I-15 SB 2+2 90th to Brg 28	07NOV98A	14NOV98A	5	
41130.0	Traffic Open Ramp 215 E to 7200 Ramp C	13NOV98A	15NOV98A	0	
41140.0	Traffic Open Ramp I-15 S to 7200 Ramp C	13NOV98A	16NOV98A	1	
41160.0	Traffic Open Ramp I-15 N to 215 E	13NOV98A	16NOV98A	1	
40010.0	Traffic Close Ramp 90-C	20NOV98A	20NOV98A	0	
41180.0	Traffic Close Ramp I-15 N to 7200 Ramp B	20NOV98A	23NOV98A	1	
43060.0	Traffic Open Ramp 45A & 45C (Phase 2)	22NOV98A	07DEC98A	8	
40007.0	Traffic Switch 106th to 1/1 Phase 2	23NOV98A	23NOV98A	1	
40009.1	Traffic Open 106th SB Off-Ramp (C)	23NOV98A	23NOV98A	1	
40009.2	Traffic Open 106th NB On-Ramp (D)	23NOV98A	23NOV98A	1	
40009.2	Traffic Open 106th NB Off-Ramp (B)	23NOV98A	23NOV98A	1	
40030.0	Traffic Switch to New SB 3+3 106th to 90th	23NOV98A	03DEC98A	8	
42320.0	Traffic Close Ramp 53-C	30NOV98A	30NOV98A	1	
42310.0	Traffic Close Ramp 53-A	01DEC98A	01DEC98A	1	
41150.0	Traffic Open Ramp I-15 N to 215 W	19DEC98A	19DEC98A	0	
47350.0	Traffic Close 500 S to NB I-15	02JAN99A	02JAN99A	1	
40070.0	Traffic Close Ramp 90-D	09JAN99A	09JAN99A	0	
41190.0	Traffic Open Ramp 7200 to I-15 N Ramp D	09JAN99A	28JUN99A	93	
41260.0	Traffic Open Ramp 7200 to 215 W	09JAN99A	30NOV00A	388	
41270.0	Traffic Open Ramp 7200 to 215 E	09JAN99A	30NOV00A	388	
41126.0	Traffic Switch to 2/2 on NB 72nd to 59th Ph 2	10JAN99A	10JAN99A	0	
47200.0	Traffic Close 500 S to SB I-15	01FEB99A	02FEB99A	2	
41200.0	Traffic Switch to new 15S215W Ramp/Bridge	25JUN99A	25JUN99A	1	
41238.0	Traffic Phase 1 I15S to 215E	25JUN99A	25JUN99A	1	
46200.0	Traffic Switch M/L to SBCD & EN-NBCD	28JUN99A	15JUL00A	209	
49020.0	Maintenance During Const. July '99 thru June '00	01JUL99A	30JUN00A	256	
41230.0	Traffic Switch Ramp 215 W to I-15 S	08JUL99A	08JUL99A	1	
43127.0	Traffic 2+2 (SB 4500S, NB 3300S) (Phase 4)	11JUL99A	08AUG99A	20	
45035.0	Traffic Open 15sc80e / 15sc15s	22JUL99A	22JUL99A	1	
46080.0	Traffic Open Ramps SBCD-1, 3, & 900S-B	30JUL99A	07MAY01A	345	
47240.0	Traffic Switch from SB 2/2 to New NB 2/2	02AUG99A	02AUG99A	1	
43126.5	Traff Close Ramps 45B&D, Build Temp Ramps (Ph 4)	08AUG99A	08AUG99A	0	
44100.0	Traffic Close Ramp 33A, 33C (Phase 4)	08AUG99A	08AUG99A	0	
44240.0	Traffic Open Ramps 33B, 33D (Phase 4)	08AUG99A	08AUG99A	0	
41128.0	Traffic Switch 2/2 new SB 72nd to 59th	21AUG99A	28AUG99A	5	
41240.0	Traffic Open Ramp I-15 S to 215 E	21AUG99A	28AUG99A	5	
42330.0	Traffic Switch to SB I-15 (Sec 1.3)	21AUG99A	28AUG99A	5	
46130.0	Traffic Switch to New NB & SB 2+2	27AUG99A	29AUG99A	1	
45003.0	Traffic Ph2 (SB 2400S, WB80)	28AUG99A	28AUG99A	0	
45040.0	Traffic Open 21s15sc / 15sc15s	28AUG99A	28AUG99A	0	
45060.0	Traffic Close 2100s Temp Ramps	28AUG99A	28AUG99A	0	
45010.0	Traffic Open 15nc21s	06SEP99A	06SEP99A	1	
45020.0	Traffic Open 21s15nc	06SEP99A	06SEP99A	1	
41185.0	Traffic Open 15N to 7200 Ramp B	08SEP99A	08SEP99A	1	
40009.3	Traffic Reclose 106th NB On-Ramp (D)	09SEP99A	09SEP99A	1	
40060.0	Traffic Close Ramp 90-B	09SEP99A	09SEP99A	1	
40110.0	Traffic Open Ramp 90-D	09SEP99A	16OCT00A	222	
47340.0	Traffic Open 400 S Surface Streets	26SEP99A	26SEP99A	0	
47340.0	Traffic Open 400 S to NB I-15 and Temp SB I-15	26SEP99A	11OCT99A	10	
45440.0	Traffic Switch 80 W to 80W15NC & 80 EB Close	04OCT99A	04OCT99A	1	

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46070.0	Traffic Close 900S-A (NB to 900S)	05OCT99A	05OCT99A	1	
47230.0	Traffic Open 600 S (In from I-15NB)	05OCT99A	05OCT99A	1	
45830.0	Traffic Switch EB 2+2	10OCT99A	11OCT99A	1	
46020.0	Traffic Close Ramp 900S-B	11OCT99A	11OCT99A	1	
42360.0	Traffic Close Ramp 53-B1	25OCT99A	25OCT99A	1	
43126.7	Traff Open Ramps 45B&D, Build Temp Ramps (Ph 5)	25OCT99A	25OCT99A	1	
41134.0	Final MOT Open 7200S Arterial	02NOV99A	03NOV99A	2	
42370.0	Traffic Close Ramp 53-D	12NOV99A	12NOV99A	1	
40008.0	Traffic Open Bridge 106th (Phase 2 Complete)	24NOV99A	24NOV99A	1	
40009.4	Traffic Reopen 106th NB On-Ramp (D)	24NOV99A	30NOV99A	4	
42375.0	Traffic Close 5300 Arterial	10JAN00A	24JAN00A	11	
46160.0	Traffic Close Ramp 1300S-B	26JAN00A	26JAN00A	1	
40085.0	Traffic Close 90th Arterial	13MAR00A	13MAR00A	1	
43200.0	Traffic Open 3900 S. Final Alignment	31MAR00A	31MAR00A	1	
46150.0	Traffic Close 1300-A, Open 900-A (NB to 900S)	01MAY00A	01MAY01A	206	
40080.0	Traffic Open New NB I-15 106th to 80th	26MAY00A	16OCT00A	99	
45850.0	Traffic Close 2100 South/900W 600W to 1050W	16JUN00A	27OCT00A	94	
46170.0	Traffic Open Final Alignment 1300S Arterial	01JUL00A	01MAY01A	164	
49030.0	Maintenance During Const. July '00 thru June '01	01JUL00A	01JUN01A	234	
42340.0	Traffic Open Ramp 53-A	10JUL00A	10JUL00A	1	
42350.0	Traffic Open Ramp 53-C	10JUL00A	10JUL00A	1	
42390.0	Traffic Open Ramp 53-B1	10JUL00A	10JUL00A	1	
42400.0	Traffic Open Ramp 53-D	10JUL00A	10JUL00A	1	
42410.0	Traffic Open 5300 Arterial	10JUL00A	10JUL00A	1	
43040.0	Traffic Close Ramp 45A,B,C,D & Arterial (Ph 7)	10JUL00A	10JUL00A	1	
45050.0	Traffic Open NC Detour to NB Traffic	10JUL00A	10JUL00A	1	
47222.0	Traffic Open I-80 E to NB I-15 (Red Path)	17JUL00A	17JUL00A	1	
40090.0	Traffic Open 90th Arterial	30SEP00A	27OCT00A	20	
46100.0	Traffic Open Ramp 1300S C (SB off)	03OCT00A	03OCT00A	1	
40040.0	Traffic Open Ramp 90-A	15OCT00A	16OCT00A	1	
40050.0	Traffic Open Ramp 90-C	15OCT00A	16OCT00A	1	
40100.0	Traffic Open Ramp 90-B	15OCT00A	16OCT00A	1	
41250.0	Traffic Open New I-15 NB 80th to 72nd	15OCT00A	15OCT00A	0	
41250.1	Traffic Open New I-15 NB 72nd to 59th	15OCT00A	15OCT00A	0	
42380.0	Traffic Open NB I-15 21+500 to 22+600	15OCT00A	15OCT00A	0	
47230.0	Traffic Open 600 S (In from I-80)	17OCT00A	17OCT00A	1	
47320.0	Traffic Open I-80 W from NB I-15 (Ramp NW)	17OCT00A	17OCT00A	1	
40140.0	Open Traffic 106th Final	01NOV00A	30NOV00A	21	
45070.0	Traffic Open 15n80e	01NOV00A	15NOV00A	6	
45080.0	Traffic Open All Lanes (2400S, State St.)	01NOV00A	30APR01A	80	
45840.0	Traffic Switch to New 201 Across Roper Yard	01NOV00A	18JUN01A	112	
43120.0	Traffic Open Ramps 45A,B,C,D & Arterial (Ph 8)	17DEC00A	18DEC00A	1	
47310.0	Traffic Open 500 S to WB I-80 (Ramp WW)	09JAN01A	30MAR01A	35	
44280.0	Traffic Close Ramps 33 A,B,C,D & Arterial (Ph 6)	10JAN01A	10JAN01A	1	
43129.0	Traffic Open All Lanes 22+100 to 26+800	16MAR01A	30APR01A	32	
47220.0	Traffic Open I-80 E to SB I-15	02APR01A	02APR01A	1	
47310.0	Traffic Open 500 S to SB I-15 (Ramp WS)	05APR01A	05APR01A	1	
46211.0	Traffic Switch to Final Alignment (Green Path)	18APR01A	18APR01A	1	
45036.0	Traffic Switch onto 15s80e	30APR01A	30APR01A	1	
47340.1	Traffic Open 400 S Ramps Final Alignment	01MAY01A	01MAY01A	1	
41290.0	Traffic Open Ramp 215 W to I-15 N	14MAY01A	14MAY01A	1	
45851.0	Traffic Open 2100 South/900W 600W to 1050W	14MAY01A	11JUL01A	41	

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46210.0	Traffic Switch to Final Alignment (Purple Path)	14MAY01A	14MAY01A	1	
47330.0	Traffic Switch to New SB & NB	16MAY01A	16MAY01A	1	
44290.0	Traffic Open Ramps 33 A,B,C,D & Arterial (Ph 7)	01JUN01A	01JUN01A	1	
47325.0	Traffic Open I-80 W from SB I-15 (Ramp SW)	06JUN01A	06JUN01A	1	
49040.0	Maintenance During Const. July '01 thru End	02JUL01A	14JUL01A	9	
41280.0	Traffic Open Ramp 215 E to I-15 N	02JUL01	02JUL01	0	

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APPENDIX E

CLOSURE SCHEDULES FOR DB AND TB ALTERNATIVES

APPENDIX F

MAJOR NORTH-SOUTH ROUTES FOR ACCIDENT ANALYSIS

I-15 between 10600 South and 600 North (Length: 17.73 miles)

Route	Mile Points	Location Description
A00015	293.78	10600 South Interchange (SR 151- 10600 South)
	310.49	600 North Interchange (Route 2354 600 North)

I-215 West of I-15 between 10600 South and I-80 (Length: 12.12)

Route	Mile Points	Location Description
A00215	13.55	Redwood Road Interchange (SR 68)
	25.67	700 North Interchange

I-215 East of I-15 between 6200 South and I-80 (Length: 7.74)

Route	Mile Points	Location Description
A00215	0.00	Junction SR-80 Split
	7.74	6200 South Interchange (SR 190 Knudsens Corner)

Bangerter Highway between 10400 South I-80 (Length: 14.2)

Route	Mile Points	Location Description
A00154	9.23	Junction 10,400 South
	23.95	Junction SR 80 Westbound off-ramp

Redwood Road between 10400 South and 600 North (Length: 15.77)

Route	Mile Points	Location Description
A00068	45.24	Junction SR 151 (10400 South)
	61.01	600 North Street (SR 268)

State Street between 10600 South and 600 North (Length: 16.83)

Route	Mile Points	Location Description
A00089	313.05	10600 South
	329.88	600 North via 300 West Street in Salt Lake City

700 East between 10600 South and 400 South (Length: 14.2)

Route	Mile Points	Location Description
A00071	5.81	10600 South Street (SR 151)
	20.01	800 South Street - 400 South Street

APPENDIX G

NUMBER OF ACCIDENTS FOR HIGHWAY AND SURFACE STREETS

Number of Accidents on Highways

Year	DB	TB	NB
1997	2,335	2,461	2,529
1998	2,124	2,350	2,548
1999	2,088	2,168	2,373
2000	2,090	2,156	2,328
2001	2,683	2,559	2,770
2002	2,593	2,432	2,602
2003	2,646	2,468	2,615
2004	2,770	2,584	2,727
2005	2,894	2,518	2,839
2006	2,963	2,962	2,878
2007	3,032	3,037	2,917
2008	3,101	3,076	2,992
2009	3,170	3,114	3,066
2010	3,239	3,152	3,141
Total	37,727	37,037	38,326

Number of Accidents on Surface Streets

Year	DB	TB	NB
1997	3,614	3,027	2,821
1998	4,447	3,292	2,419
1999	4,371	3,852	2,431
2000	4,398	3,757	2,717
2001	2,936	2,974	2,129
2002	2,429	3,626	2,422
2003	1,660	3,266	2,487
2004	1,990	4,490	2,908
2005	2,320	4,664	3,329
2006	2,504	3,560	3,520
2007	2,687	3,375	3,712
2008	2,995	3,652	4,050
2009	3,302	3,929	4,388
2010	3,610	4,206	4,727
Total	43,263	51,671	44,060

Number of Accidents on Highways and Surface Streets

Year	DB	TB	NB
1997	3,614	3,027	2,821
1998	4,447	3,292	2,419
1999	4,371	3,852	2,431
2000	4,398	3,757	2,717
2001	2,936	2,974	2,129
2002	2,429	3,626	2,422
2003	1,660	3,266	2,487
2004	1,990	4,490	2,908
2005	2,320	4,664	3,329
2006	2,504	3,560	3,520
2007	2,687	3,375	3,712
2008	2,995	3,652	4,050
2009	3,302	3,929	4,388
2010	3,610	4,206	4,727
Total	43,263	51,671	44,060

APPENDIX H

DATA SETS FOR ACCIDENT ANALYSIS

Salt Lake County					
Season	Accidents	VMT	Intersection	Construction	Congestion
Winter-96	7,299	1,616,800,212	13	0	0.30
Spring-96	6,256	1,742,474,414	13	0	0.30
Summer-96	6,788	1,739,974,757	13	0	0.30
Fall-96	7,499	1,690,319,314	13	0	0.30
Winter-97	5,991	1,614,800,415	13	0	0.27
Spring-97	6,212	1,798,114,858	11	11	0.28
Summer-97	6,367	1,815,456,471	9	17	0.31
Fall-97	6,832	1,731,795,732	7	17	0.31
Winter-98	5,944	1,685,448,840	7	17	0.31
Spring-98	5,914	1,855,975,447	6	17	0.31
Summer-98	6,241	1,800,911,064	6	17	0.31
Fall-98	6,671	1,726,966,997	7	17	0.31
Winter-99	5,509	1,666,129,444	9	17	0.31
Spring-99	5,970	1,873,670,166	8	17	0.31
Summer-99	6,233	1,813,083,975	7	17	0.31
Fall-99	6,595	1,850,010,412	7	17	0.31
Winter-00	5,807	1,766,776,132	6	17	0.31
Spring-00	5,533	1,904,934,533	6	18	0.31
Summer-00	5,779	1,917,851,081	7	18	0.30
Fall-00	6,200	1,730,362,369	8	18	0.30
Winter-01	5,215	1,751,506,283	9	18	0.29
Spring-01	5,508	1,905,227,229	11	6	0.28
Summer-01	5,109	2,071,732,965	12	0	0.22
Fall-01	6,323	1,991,281,108	13	0	0.21

State Street					
Season	Accidents	VMT	Intersection	Construction	Congestion
Winter-96	277	45094452	13	0	0.30
Spring-96	301	48599653	13	0	0.30
Summer-96	330	48529935	13	0	0.30
Fall-96	354	47144986	13	0	0.30
Winter-97	279	47115465	13	0	0.27
Spring-97	326	52464080	11	11	0.28
Summer-97	424	52970061	9	17	0.31
Fall-97	451	50529069	7	17	0.31
Winter-98	369	54201216	7	17	0.31
Spring-98	408	59685066	6	17	0.31
Summer-98	458	57914288	6	17	0.31
Fall-98	452	55536370	7	17	0.31
Winter-99	351	52549644	9	17	0.31
Spring-99	427	59095468	8	17	0.31
Summer-99	427	57184582	7	17	0.31
Fall-99	418	58349241	7	17	0.31
Winter-00	370	53843642	6	17	0.31
Spring-00	402	58054108	6	18	0.31
Summer-00	397	58447748	7	18	0.30
Fall-00	351	52733909	8	18	0.30
Winter-01	279	41423682	9	18	0.29
Spring-01	287	45059232	11	6	0.28
Summer-01	239	48997145	12	0	0.22
Fall-01	264	47094433	13	0	0.21

Redwood Road					
Season	Accidents	VMT	Intersection	Construction	Congestion
Winter-96	243	42318582	13	0	0.30
Spring-96	279	45608014	13	0	0.30
Summer-96	292	45542587	13	0	0.30
Fall-96	318	44242892	13	0	0.30
Winter-97	226	42767752	13	0	0.27
Spring-97	271	47622808	11	11	0.28
Summer-97	282	48082098	9	17	0.31
Fall-97	281	45866355	7	17	0.31
Winter-98	265	47073388	7	17	0.31
Spring-98	266	51836075	6	17	0.31
Summer-98	330	50298166	6	17	0.31
Fall-98	330	48232960	7	17	0.31
Winter-99	256	45204648	9	17	0.31
Spring-99	270	50835547	8	17	0.31
Summer-99	316	49191750	7	17	0.31
Fall-99	377	50193621	7	17	0.31
Winter-00	272	47948097	6	17	0.31
Spring-00	268	51697544	6	18	0.31
Summer-00	293	52048083	7	18	0.30
Fall-00	268	46959873	8	18	0.30
Winter-01	234	43163434	9	18	0.29
Spring-01	279	46951672	11	6	0.28
Summer-01	227	51054974	12	0	0.22
Fall-01	276	49072350	13	0	0.21

I-15					
Season	Accidents	VMT	Intersection	Construction	Congestion
Winter-96	497	219,397,412	13	0	0.30
Spring-96	395	236,451,217	13	0	0.30
Summer-96	401	236,112,017	13	0	0.30
Fall-96	475	229,373,846	13	0	0.30
Winter-97	358	175,864,179	13	0	0.27
Spring-97	342	195,828,532	11	11	0.28
Summer-97	316	197,717,167	9	17	0.31
Fall-97	326	188,605,869	7	17	0.31
Winter-98	337	126,245,683	7	17	0.31
Spring-98	265	139,018,689	6	17	0.31
Summer-98	206	134,894,185	6	17	0.31
Fall-98	245	129,355,530	7	17	0.31
Winter-99	265	115,008,040	9	17	0.31
Spring-99	256	129,333,969	8	17	0.31
Summer-99	199	125,151,882	7	17	0.31
Fall-99	253	127,700,805	7	17	0.31
Winter-00	209	130,314,893	6	17	0.31
Spring-00	197	140,505,260	6	18	0.31
Summer-00	229	141,457,967	7	18	0.30
Fall-00	296	127,629,066	8	18	0.30
Winter-01	260	215,266,574	9	18	0.29
Spring-01	272	234,159,445	11	6	0.28
Summer-01	360	254,623,613	12	0	0.22
Fall-01	473	244,735,784	13	0	0.21

Bangerter Highway					
Season	Accidents	VMT	Intersection	Construction	Congestion
Winter-96	87	38,816,947	13	0	0.30
Spring-96	54	41,834,196	13	0	0.30
Summer-96	54	41,774,183	13	0	0.30
Fall-96	75	40,582,030	13	0	0.30
Winter-97	91	43,244,808	13	0	0.27
Spring-97	75	48,154,020	11	11	0.28
Summer-97	66	48,618,433	9	17	0.31
Fall-97	89	46,377,975	7	17	0.31
Winter-98	108	52,086,924	7	17	0.31
Spring-98	74	57,356,859	6	17	0.31
Summer-98	83	55,655,156	6	17	0.31
Fall-98	104	53,369,997	7	17	0.31
Winter-99	86	49,516,916	9	17	0.31
Spring-99	88	55,684,971	8	17	0.31
Summer-99	103	53,884,365	7	17	0.31
Fall-99	112	54,981,809	7	17	0.31
Winter-00	84	50,002,803	6	17	0.31
Spring-00	77	53,912,923	6	18	0.31
Summer-00	95	54,278,484	7	18	0.30
Fall-00	89	48,972,231	8	18	0.30
Winter-01	91	47,411,321	9	18	0.29
Spring-01	64	51,572,376	11	6	0.28
Summer-01	61	56,079,501	12	0	0.22
Fall-01	105	53,901,759	13	0	0.21

700 East					
Season	Accidents	VMT	Intersection	Construction	Congestion
Winter-96	200	41,290,696	13	0	0.30
Spring-96	157	44,500,231	13	0	0.30
Summer-96	181	44,436,393	13	0	0.30
Fall-96	199	43,168,266	13	0	0.30
Winter-97	201	43,913,692	13	0	0.27
Spring-97	193	48,898,837	11	11	0.28
Summer-97	218	49,370,433	9	17	0.31
Fall-97	253	47,095,321	7	17	0.31
Winter-98	213	52,764,744	7	17	0.31
Spring-98	235	58,103,258	6	17	0.31
Summer-98	240	56,379,410	6	17	0.31
Fall-98	271	54,064,513	7	17	0.31
Winter-99	211	50,547,585	9	17	0.31
Spring-99	221	56,844,024	8	17	0.31
Summer-99	222	55,005,940	7	17	0.31
Fall-99	261	56,126,227	7	17	0.31
Winter-00	168	39,576,003	6	17	0.31
Spring-00	171	43,049,391	6	18	0.31
Summer-00	161	46,811,657	7	18	0.30
Fall-00	163	44,993,814	8	18	0.30
Winter-01	185	49,574,659	9	18	0.29
Spring-01	196	53,451,299	11	6	0.28
Summer-01	210	53,813,730	12	0	0.22
Fall-01	232	48,552,911	13	0	0.21

I-215 West					
Season	Accidents	VMT	Intersection	Construction	Congestion
Winter-96	169	70,445,625	13	0	0.30
Spring-96	37	75,921,377	13	0	0.30
Summer-96	74	75,812,465	13	0	0.30
Fall-96	88	73,648,927	13	0	0.30
Winter-97	107	82,673,807	13	0	0.27
Spring-97	75	92,059,055	11	11	0.28
Summer-97	101	92,946,903	9	17	0.31
Fall-97	133	88,663,679	7	17	0.31
Winter-98	150	102,752,045	7	17	0.31
Spring-98	104	113,148,063	6	17	0.31
Summer-98	132	109,791,107	6	17	0.31
Fall-98	145	105,283,166	7	17	0.31
Winter-99	112	102,555,403	9	17	0.31
Spring-99	121	115,330,174	8	17	0.31
Summer-99	112	111,600,907	7	17	0.31
Fall-99	125	113,873,843	7	17	0.31
Winter-00	134	98,028,322	6	17	0.31
Spring-00	103	105,693,943	6	18	0.31
Summer-00	119	106,410,608	7	18	0.30
Fall-00	163	96,007,930	8	18	0.30
Winter-01	166	80,701,802	9	18	0.29
Spring-01	105	87,784,595	11	6	0.28
Summer-01	67	95,456,456	12	0	0.22
Fall-01	143	91,749,584	13	0	0.21

I-215 East					
Season	Accidents	VMT	Intersection	Construction	Congestion
Winter-96	92	31,223,740	13	0	0.30
Spring-96	45	33,650,767	13	0	0.30
Summer-96	35	33,602,494	13	0	0.30
Fall-96	83	32,643,545	13	0	0.30
Winter-97	86	30,207,322	13	0	0.27
Spring-97	54	33,636,500	11	11	0.28
Summer-97	41	33,960,901	9	17	0.31
Fall-97	62	32,395,899	7	17	0.31
Winter-98	75	29,265,884	7	17	0.31
Spring-98	46	32,226,882	6	17	0.31
Summer-98	57	31,270,753	6	17	0.31
Fall-98	82	29,986,799	7	17	0.31
Winter-99	59	28,964,704	9	17	0.31
Spring-99	79	32,572,680	8	17	0.31
Summer-99	56	31,519,424	7	17	0.31
Fall-99	54	32,161,369	7	17	0.31
Winter-00	60	30,827,574	6	17	0.31
Spring-00	48	33,238,230	6	18	0.31
Summer-00	53	33,463,604	7	18	0.30
Fall-00	81	30,192,209	8	18	0.30
Winter-01	67	29,756,184	9	18	0.29
Spring-01	48	32,367,735	11	6	0.28
Summer-01	33	35,196,486	12	0	0.22
Fall-01	62	33,829,697	13	0	0.21

APPENDIX I

VISUM OUTPUT FILES USED IN THE ACCIDENT ANALYSIS

Design Build Alternative Excel Files

Excel File	Period of Time Modeled
NB1996	Whole 1996
1997Jan-Apr	Jan, Feb, Mar, and Apr 1997
1997May	May 1997
1997Jun	Jun 1997
1997Jul	Jul 1997
1997Aug	Aug 1997
1997Sep	Sept 1997
1997Oct	Oct 1997
1997Nov-Dec	Nov and Dec 1997
1998Jan-Mar	Jan, Feb, and Mar 1998
1998Apr-May	Apr and May 1998
1998Jun-Jul	Jun and Jul 1998
1998Aug	Aug 1998
1998Sep	Sept 1998
1998Oct	Oct 1998
1998Nov	Nov 1998
1998Dec	Dec 1998
1999Jan	Jan 1999
1999Feb-May	Feb, Mar, and May 1999
1999Jun-Jul	Jun and Jul 1999
1999Aug	Aug 1999
1999Sep	Sept 1999

Excel File	Period of Time Modeled
1999Oct	Oct 1999
1999Nov	Nov 1999
1999Dec	Dec 1999
2000Jan-Feb	Jan and Feb 2000
2000Mar-May	Mar, Apr, and May 2000
2000 Jun	Jun 2000
2000Jul	Jul 2000
2000Aug-Sep	Aug and Sept 2000
2000Oct	Oct 2000
2000Nov	Nov 2000
2000Dec	Dec 2000
2001Jan	Jan 2001
2001Feb-Mar	Feb and Mar 2001
2001Apr	Apr 2001
2001May	May 2001
2001Jun	Jun 20001
2001Jul	Jul 2001
2001New	Aug, Sept, Oct, Nov, Dec 2001
2003All	Whole 2003
2005All	Whole 2005
2007All	Whole 2007
2010All	Whole 2010

Traditional Build Alternative Excel Files

Excel File	Period of Time Modeled
NB1996	Whole 1996
1997Fall	Fall 1997
1997Winter	Winter 1997
1997Spring-Summer	Spring and Summer 1997
1998Fall	Fall 1998
1998Winter	Winter 1998
1998Spring-Summer	Spring and Summer 1998
1999Winter	Fall and Winter 1999
1999Spring	Spring and Summer 1999
2000AllSeasons	Whole 2000
2001Fall-Winter	Fall and Winter 2001
2001Spring-Summer	Spring and Summer 2001
2002Fall-Winter	Fall and Winter 2002
2002Spring-Summer	Spring and Summer 2002
2003Fall-Winter	Fall and Winter 2003
2003Spring-Summer	Spring and Summer 2003
2004Spring-Fall	Fall, Spring, and Summer 2004
2004Winter	Winter 2004
2005AllSeasons	Whole 2005
2006AllSeasons	Whole 2006
2007AllSeasons	Whole 2007
2010All	Whole 2010

No Build Alternative Excel Files

Excel File	Period of Time Modeled
NB1996	Whole 1996
NB1997	Whole 1997
NB1998	Whole 1998
NB1999	Whole 1999
NB2000	Whole 2000
NB2001	Whole 2001
NB2003	Whole 2003
NB2005	Whole 2005
NB2007	Whole 2007
NB2010	Whole 2010

APPENDIX J

MOBILE 6 INPUT FILE – DESIGN-BUILD SUMMER

```
MOBILE6 INPUT FILE :
*--------------------------------------------------------*
* F:\SHARED\JORY\Mobile62\Conform\F5Newmix\M6Con_F5.in      *
* by Jory Johner, August 2002                          *
* Mobile6.2 input file for WFRC 2001 Conformity analysis    *
*   - Use Mobile6.2/UDOT VMT mix, and new Fvmt format       *
*     (one composite emission factor for each year for all  *
*       facility types)                          *
* SL, DA, WE, & UT counties - Ogden & Salt Lake Cities      *
* M6.2 SL "Test Only", other counties "Test & Repair"       *
* Include: NewIM, Vehicle Age, PM10 SIP Temp               *
* Change Abslute humidity: Summer = 51.3, Winter = 20.0,    *
* SL PM10 Winter = 26.8                                *
* Use UDOT 2001 vehcile type counts and M6 % growth by      *
* vehcile type for VMT fraction.                       *
*--------------------------------------------------------*

*==Header Section===========================================================
> WFRC 2001 Conformity - 2030 LRP.

POLLUTANTS        : HC CO NOx
*PARTICULATES      :
SPREADSHEET       :
REPORT FILE       : D:\Utes\Emission\M6UTLDB.out

RUN DATA

************************************************************************
************************************************************************
********************* SALT LAKE COUNTY SUMMER **********************
************************************************************************
************************************************************************

*==Run Section:  Salt Lake Co. Summer 1968-1997 ===============================
> SLCo. summer, COMPOSITE (All roads) 1968-1997

*************************************
* Ouput Commnands - Vehicle Detail   *
*************************************
NO REFUELING       :
EXPRESS HC AS VOC  :

*************************************
* External Conditions (Weather)      *
*************************************
* Use default hourly temperature profile
* Min/Max temperature is 23-45 in winter, 63-98 in summer
* Absolute humidity is [xx20xx] 36.8 in winter and 51.3 in summmer

ABSOLUTE HUMIDITY  : 51.3
MIN/MAX TEMP       : 63. 98.
```

```
*************************************
* Fleet Conditions                  *
*************************************
* Use Salt Lake Co. 7/2001 vehicle age data

REG DIST          : D:\Utes\Emission\Slage02.d

*****************************************
* Activity Commands (VMT, Starts, Trips) *
*****************************************
* Use WFRC VMT by hour in scenario section
* Use 28-vehicle Fvmt by year in scenario section
* Use WFRC VMT by speed in scenario section
* Use WFRC composite VMT mix by year in scenario section
* Use default weekday trip length profiles

*WE DA TRI LEN DI   : F:\SHARED\JORY\Mobile62\Conform\WDTL_96.d

***************************************
* State Programs (County I/M & ATP)    *
***************************************
I/M DESCRIPT FILE  : D:\Utes\Emission\SL6897to.d

*Define SLCo ATP Program - Begin ATP 1984, covers models 1968-2050,
*test all vehicle types (14), place holder "1", annual test,
*96% compliance, all inspections but "lead test".

ANTI-TAMP PROG     :
84 68 50 22222 22222222 2 11 096. 22212222
I/M CREDIT FILE    : D:\Utes\Emission\Tech12.d

*******************************
* Fuel Commands               *
*******************************
*Conventional Gasoline West (3), summer RVP = 12.1, summer RVP = 7.8

FUEL PROGRAM       : 3
FUEL RVP          : 7.8


*==Scenario Section: Salt Lake Co. Summer 1968-1997 ===============================
> SLCo. summer, COMPOSITE (All roads) 1968-1997


*** Use Mobile6/UDOT (UM6) adjusted VMT Fraction in Mobile6 format **************


SCENARIO RECORD    : DB1996s
CALENDAR YEAR      : 1996
ALTITUDE          : 2
```

*PARTICLE SIZE : 10.0
*PARTICULATE EF : PMGZML.CSV PMGDR1.CSV PMGDR2.CSV PMDZML.CSV PMDDR1.CSV PMDDR2.CSV
DIESEL SULFUR : 330.00
VMT BY HOUR : D:\Utes\Emission\HvmtSL96.d
SPEED VMT : D:\Utes\Emission\Utl_vmt\Db\SvmtDB96.d
VMT BY FACILITY : D:\Utes\Emission\Utl_vmt\Db\FvmtDB96.d
VMT FRACTIONS :
0.5955 0.0551 0.1836 0.0565 0.0259 0.0251 0.0026 0.0017
0.0013 0.0052 0.0063 0.0071 0.0252 0.0012 0.0006 0.0071

SCENARIO RECORD : DB1997s
CALENDAR YEAR : 1997
ALTITUDE : 2
*PARTICLE SIZE : 10.0
*PARTICULATE EF : PMGZML.CSV PMGDR1.CSV PMGDR2.CSV PMDZML.CSV PMDDR1.CSV PMDDR2.CSV
DIESEL SULFUR : 330.00
VMT BY HOUR : D:\Utes\Emission\HvmtSL96.d
SPEED VMT : D:\Utes\Emission\Utl_vmt\Db\SvmtDB97.d
VMT BY FACILITY : D:\Utes\Emission\Utl_vmt\Db\FvmtDB97.d
VMT FRACTIONS :
0.5955 0.0551 0.1836 0.0565 0.0259 0.0251 0.0026 0.0017
0.0013 0.0052 0.0063 0.0071 0.0252 0.0012 0.0006 0.0071

END OF RUN

*==Run Section: Composite 1998-2003 ==============================
> SLCo. summer COMPOSITE (All roads) 1998-2003

****
* Ouput Commnands - Vehicle Detail *
****
NO REFUELING :
EXPRESS HC AS VOC :

****
* External Conditions (Weather) *
****
* Use default hourly temperature profile
* Min/Max temperature is 23-45 in summer, 63-98 in summer
* Absolute humidity is 26.8 in winter and 51.3 in summmer

ABSOLUTE HUMIDITY : 51.3
MIN/MAX TEMP : 63. 98.

****
* Fleet Conditions *
****
* Use Salt Lake Co. 7/2001 vehicle age data

```
REG DIST          : D:\Utes\Emission\Slage02.d

******************************************
* Activity Commands (VMT, Starts, Trips) *
******************************************
* Use WFRC VMT by hour in scenario section
* Use 28-vehicle Fvmt by year in scenario section
* Use WFRC VMT by speed in scenario section
* Use WFRC composite VMT mix by year in scenario section
* Use default weekday trip length profiles

*WE DA TRI LEN DI   : F:\SHARED\JORY\Mobile62\Conform\WDTL_96.d

****************************************
* State Programs (County I/M & ATP)    *
****************************************
I/M DESCRIPT FILE  : D:\Utes\Emission\SL9850to.d

*Define SLCo ATP Program - Begin ATP 1984, covers models 1968-2050,
*test all vehicle types (14), place holder "1", annual test,
*96% compliance, all inspections but "lead test".

ANTI-TAMP PROG     :
84 68 50 22222 22222222 2 11 096. 22212222
I/M CREDIT FILE    : D:\Utes\Emission\Tech12.d

********************************
* Fuel Commands                *
********************************
*Conventional Gasoline West (3), summer RVP = 12.1, summer RVP = 7.8

FUEL PROGRAM       : 3
FUEL RVP           : 7.8


*==Scenario Section: Composite 1998-2003 ===============================
> SLCo. summer, Composite (All roads) 1998-2003

*** Use Mobile6/UDOT adjusted VMT Fraction in Mobile6 format **************

SCENARIO RECORD    : DB1998s
CALENDAR YEAR      : 1998
ALTITUDE           : 2
*PARTICLE SIZE     : 10.0
*PARTICULATE   EF             :   PMGZML.CSV   PMGDR1.CSV   PMGDR2.CSV   PMDZML.CSV
PMDDR1.CSV PMDDR2.CSV
DIESEL SULFUR      : 330.00
VMT BY HOUR        : D:\Utes\Emission\HvmtSL96.d
SPEED VMT          : D:\Utes\Emission\Utl_vmt\Db\SvmtDB98.d
VMT BY FACILITY    : D:\Utes\Emission\Utl_vmt\Db\FvmtDB98.d
```

VMT FRACTIONS :
0.5367 0.0646 0.2152 0.0663 0.0306 0.0261 0.0026 0.0019
0.0014 0.0056 0.0067 0.0074 0.0264 0.0012 0.0006 0.0067

SCENARIO RECORD : DB1999s
CALENDAR YEAR : 1999
ALTITUDE : 2
*PARTICLE SIZE : 10.0
*PARTICULATE EF : PMGZML.CSV PMGDR1.CSV PMGDR2.CSV PMDZML.CSV PMDDR1.CSV PMDDR2.CSV
DIESEL SULFUR : 330.00
VMT BY HOUR : D:\Utes\Emission\HvmtSL96.d
SPEED VMT : D:\Utes\Emission\Utl_vmt\Db\SvmtDB99.d
VMT BY FACILITY : D:\Utes\Emission\Utl_vmt\Db\FvmtDB99.d
VMT FRACTIONS :
0.5367 0.0646 0.2152 0.0663 0.0306 0.0261 0.0026 0.0019
0.0014 0.0056 0.0067 0.0074 0.0264 0.0012 0.0006 0.0067

SCENARIO RECORD : DB2000s
CALENDAR YEAR : 2000
ALTITUDE : 2
*PARTICLE SIZE : 10.0
*PARTICULATE EF : PMGZML.CSV PMGDR1.CSV PMGDR2.CSV PMDZML.CSV PMDDR1.CSV PMDDR2.CSV
DIESEL SULFUR : 330.00
VMT BY HOUR : D:\Utes\Emission\HvmtSL96.d
SPEED VMT : D:\Utes\Emission\Utl_vmt\Db\SvmtDB00.d
VMT BY FACILITY : D:\Utes\Emission\Utl_vmt\Db\FvmtDB00.d
VMT FRACTIONS :
0.5155 0.0682 0.2268 0.0699 0.0322 0.0262 0.0026 0.0020
0.0015 0.0057 0.0068 0.0075 0.0267 0.0013 0.0006 0.0065

SCENARIO RECORD : DB2001s
CALENDAR YEAR : 2001
ALTITUDE : 2
*PARTICLE SIZE : 10.0
*PARTICULATE EF : PMGZML.CSV PMGDR1.CSV PMGDR2.CSV PMDZML.CSV PMDDR1.CSV PMDDR2.CSV
DIESEL SULFUR : 330.00
VMT BY HOUR : D:\Utes\Emission\HvmtSL96.d
SPEED VMT : D:\Utes\Emission\Utl_vmt\Db\SvmtDB01.d
VMT BY FACILITY : D:\Utes\Emission\Utl_vmt\Db\FvmtDB01.d
VMT FRACTIONS :
0.4982 0.0710 0.2367 0.0730 0.0335 0.0263 0.0026 0.0021
0.0015 0.0057 0.0068 0.0075 0.0268 0.0013 0.0006 0.0064

SCENARIO RECORD : DB2002s
CALENDAR YEAR : 2002
ALTITUDE : 2
*PARTICLE SIZE : 10.0

*PARTICULATE EF : PMGZML.CSV PMGDR1.CSV PMGDR2.CSV PMDZML.CSV PMDDR1.CSV PMDDR2.CSV
DIESEL SULFUR : 330.00
VMT BY HOUR : D:\Utes\Emission\HvmtSL96.d
SPEED VMT : D:\Utes\Emission\Utl_vmt\Db\SvmtDB02.d
VMT BY FACILITY : D:\Utes\Emission\Utl_vmt\Db\FvmtDB02.d
VMT FRACTIONS :
0.4842 0.0734 0.2447 0.0754 0.0347 0.0264 0.0026 0.0020
0.0015 0.0057 0.0069 0.0075 0.0269 0.0013 0.0006 0.0062

SCENARIO RECORD : DB2003s
CALENDAR YEAR : 2003
ALTITUDE : 2
*PARTICLE SIZE : 10.0
*PARTICULATE EF : PMGZML.CSV PMGDR1.CSV PMGDR2.CSV PMDZML.CSV PMDDR1.CSV PMDDR2.CSV
DIESEL SULFUR : 330.00
VMT BY HOUR : D:\Utes\Emission\HvmtSL3.d
SPEED VMT : D:\Utes\Emission\Utl_vmt\Db\SvmtDB03.d
VMT BY FACILITY : D:\Utes\Emission\Utl_vmt\Db\FvmtDB03.d
VMT FRACTIONS :
0.4695 0.0758 0.2528 0.0778 0.0358 0.0265 0.0026 0.0021
0.0015 0.0059 0.0070 0.0076 0.0271 0.0013 0.0006 0.0061

END OF RUN

*==Run Section: Composite 2004-2050 ==============================
> SLCo. summer COMPOSITE (All roads) 2004-2050

****
* Ouput Commnands - Vehicle Detail *
****
NO REFUELING :
EXPRESS HC AS VOC :

****
* External Conditions (Weather) *
****
* Use default hourly temperature profile
* Min/Max temperature is 23-45 in summer, 63-98 in summer
* Absolute humidity is 26.8 in winter and 51.3 in summmer

ABSOLUTE HUMIDITY : 51.3
MIN/MAX TEMP : 63. 98.

****
* Fleet Conditions *
****
* Use Salt Lake Co. 7/2001 vehicle age data

REG DIST : D:\Utes\Emission\SLage02.d

```
*****************************************
* Activity Commands (VMT, Starts, Trips) *
*****************************************
* Use WFRC VMT by hour in scenario section
* Use 28-vehicle Fvmt by year in scenario section
* Use WFRC VMT by speed in scenario section
* Use WFRC composite VMT mix by year in scenario section
* Use default weekday trip length profiles

*WE DA TRI LEN DI   : F:\SHARED\JORY\Mobile62\Conform\WDTL_96.d

***************************************
* State Programs (County I/M & ATP)    *
***************************************
I/M DESCRIPT FILE  : D:\Utes\Emission\SL9850to.d

*Define SLCo ATP Program - Begin ATP 1984, covers models 1968-2050,
*test all vehicle types (14), place holder "1", annual test,
*96% compliance, all inspections but "lead test".

ANTI-TAMP PROG     :
84 68 50 22222 22222222 2 11 096. 22212222
I/M CREDIT FILE    : D:\Utes\Emission\Tech12.d

*******************************
* Fuel Commands                *
*******************************
*Conventional Gasoline West (3), summer RVP = 12.1, summer RVP = 7.8

FUEL PROGRAM       : 3
FUEL RVP           : 7.8


*==Scenario Section: Composite 2004-2050 ==============================
> SLCo. summer, Composite (All roads) 2004-2050

*** Use Mobile6/UDOT adjusted VMT Fraction in Mobile6 format **************

SCENARIO RECORD    : DB2004s
CALENDAR YEAR      : 2004
ALTITUDE           : 2
*PARTICLE SIZE      : 10.0
*PARTICULATE   EF             :   PMGZML.CSV   PMGDR1.CSV   PMGDR2.CSV   PMDZML.CSV
PMDDR1.CSV PMDDR2.CSV
DIESEL SULFUR      : 330.00
VMT BY HOUR        : D:\Utes\Emission\HvmtSL4.d
SPEED VMT          : D:\Utes\Emission\Utl_vmt\Db\SvmtDB03.d
VMT BY FACILITY    : D:\Utes\Emission\Utl_vmt\Db\FvmtDB03.d
VMT FRACTIONS      :
0.4550 0.0783 0.2608 0.0804 0.0370 0.0266 0.0026 0.0021
```

0.0016 0.0059 0.0070 0.0076 0.0272 0.0013 0.0006 0.0060

SCENARIO RECORD : DB2005s
CALENDAR YEAR : 2005
ALTITUDE : 2
*PARTICLE SIZE : 10.0
*PARTICULATE EF : PMGZML.CSV PMGDR1.CSV PMGDR2.CSV PMDZML.CSV PMDDR1.CSV PMDDR2.CSV
DIESEL SULFUR : 330.00
VMT BY HOUR : D:\Utes\Emission\HvmtSL4.d
SPEED VMT : D:\Utes\Emission\Utl_vmt\Db\SvmtDB05.d
VMT BY FACILITY : D:\Utes\Emission\Utl_vmt\Db\FvmtDB05.d
VMT FRACTIONS :
0.4411 0.0807 0.2687 0.0828 0.0380 0.0267 0.0026 0.0021
0.0016 0.0059 0.0070 0.0077 0.0273 0.0013 0.0006 0.0059

SCENARIO RECORD : DB2006s
CALENDAR YEAR : 2006
ALTITUDE : 2
*PARTICLE SIZE : 10.0
*PARTICULATE EF : PMGZML.CSV PMGDR1.CSV PMGDR2.CSV PMDZML.CSV PMDDR1.CSV PMDDR2.CSV
DIESEL SULFUR : 330.00
VMT BY HOUR : D:\Utes\Emission\HvmtSL6.d
SPEED VMT : D:\Utes\Emission\Utl_vmt\Db\SvmtDB05.d
VMT BY FACILITY : D:\Utes\Emission\Utl_vmt\Db\FvmtDB05.d
VMT FRACTIONS :
0.4271 0.0831 0.2767 0.0853 0.0392 0.0267 0.0026 0.0021
0.0016 0.0059 0.0070 0.0077 0.0273 0.0013 0.0006 0.0058

SCENARIO RECORD : DB2007s
CALENDAR YEAR : 2007
ALTITUDE : 2
*PARTICLE SIZE : 10.0
*PARTICULATE EF : PMGZML.CSV PMGDR1.CSV PMGDR2.CSV PMDZML.CSV PMDDR1.CSV PMDDR2.CSV
DIESEL SULFUR : 330.00
VMT BY HOUR : D:\Utes\Emission\HvmtSL6.d
SPEED VMT : D:\Utes\Emission\Utl_vmt\Db\SvmtDB07.d
VMT BY FACILITY : D:\Utes\Emission\Utl_vmt\Db\FvmtDB07.d
VMT FRACTIONS :
0.4120 0.0857 0.2852 0.0879 0.0404 0.0267 0.0026 0.0021
0.0017 0.0060 0.0070 0.0077 0.0273 0.0014 0.0006 0.0057

SCENARIO RECORD : DB2008s
CALENDAR YEAR : 2008
ALTITUDE : 2
*PARTICLE SIZE : 10.0
*PARTICULATE EF : PMGZML.CSV PMGDR1.CSV PMGDR2.CSV PMDZML.CSV PMDDR1.CSV PMDDR2.CSV
DIESEL SULFUR : 330.00

VMT BY HOUR : D:\Utes\Emission\HvmtSL6.d
SPEED VMT : D:\Utes\Emission\Utl_vmt\Db\SvmtDB07.d
VMT BY FACILITY : D:\Utes\Emission\Utl_vmt\Db\FvmtDB07.d
VMT FRACTIONS :
0.3969 0.0882 0.2937 0.0905 0.0416 0.0269 0.0026 0.0022
0.0017 0.0060 0.0070 0.0077 0.0274 0.0013 0.0006 0.0057

SCENARIO RECORD : DB2009s
CALENDAR YEAR : 2009
ALTITUDE : 2
*PARTICLE SIZE : 10.0
*PARTICULATE EF : PMGZML.CSV PMGDR1.CSV PMGDR2.CSV PMDZML.CSV PMDDR1.CSV PMDDR2.CSV
DIESEL SULFUR : 330.00
VMT BY HOUR : D:\Utes\Emission\HvmtSL6.d
SPEED VMT : D:\Utes\Emission\Utl_vmt\Db\SvmtDB10.d
VMT BY FACILITY : D:\Utes\Emission\Utl_vmt\Db\FvmtDB10.d
VMT FRACTIONS :
0.3828 0.0906 0.3017 0.0930 0.0427 0.0269 0.0026 0.0022
0.0017 0.0060 0.0070 0.0077 0.0275 0.0014 0.0006 0.0056

SCENARIO RECORD : DB2010s
CALENDAR YEAR : 2010
ALTITUDE : 2
*PARTICLE SIZE : 10.0
*PARTICULATE EF : PMGZML.CSV PMGDR1.CSV PMGDR2.CSV PMDZML.CSV PMDDR1.CSV PMDDR2.CSV
DIESEL SULFUR : 330.00
VMT BY HOUR : D:\Utes\Emission\HvmtSL6.d
SPEED VMT : D:\Utes\Emission\Utl_vmt\Db\SvmtDB10.d
VMT BY FACILITY : D:\Utes\Emission\Utl_vmt\Db\FvmtDB10.d
VMT FRACTIONS :
0.3696 0.0929 0.3092 0.0953 0.0438 0.0269 0.0026 0.0021
0.0016 0.0060 0.0071 0.0077 0.0276 0.0014 0.0006 0.0056

END OF RUN

****
****
********************** SALT LAKE COUNTY WINTER **********************
****
****

*==Run Section: Salt Lake Co. Winter 1968-1997 ==============================
> SLCo. winter, COMPOSITE (All roads) 1968-1997

****
* Ouput Commnands - Vehicle Detail *
****
NO REFUELING :

```
EXPRESS HC AS VOC  :

*************************************
* External Conditions (Weather)      *
*************************************
* Use default hourly temperature profile
* Min/Max temperature is 23-45 in winter, 63-98 in summer
* Absolute humidity is 26.8 in winter and 51.3 in summmer

ABSOLUTE HUMIDITY  : 26.8
MIN/MAX TEMP       : 35. 45.

*************************************
* Fleet Conditions                  *
*************************************
* Use Salt Lake Co. 7/2001 vehicle age data

REG DIST           : D:\Utes\Emission\SLage02.d

*****************************************
* Activity Commands (VMT, Starts, Trips) *
*****************************************
* Use WFRC VMT by hour in scenario section
* Use 28-vehicle Fvmt by year in scenario section
* Use WFRC VMT by speed in scenario section
* Use WFRC composite VMT mix by year in scenario section
* Use default weekday trip length profiles

*WE DA TRI LEN DI   : F:\SHARED\JORY\Mobile62\Conform\WDTL_96.d

***************************************
* State Programs (County I/M & ATP)    *
***************************************
I/M DESCRIPT FILE  : D:\Utes\Emission\SL6897to.d

*Define SLCo ATP Program - Begin ATP 1984, covers models 1968-2050,
*test all vehicle types (14), place holder "1", annual test,
*96% compliance, all inspections but "lead test".

ANTI-TAMP PROG     :
84 68 50 22222 22222222 2 11 096. 22212222
I/M CREDIT FILE    : D:\Utes\Emission\Tech12.d

******************************
* Fuel Commands              *
******************************
*Conventional Gasoline West (3), winter RVP = 12.1, summer RVP = 7.8

FUEL PROGRAM       : 3
FUEL RVP           : 12.1
```

```
*==Scenario Section: Salt Lake Co. Winter 1968-1997 ================================
> SLCo. winter, COMPOSITE (All roads) 1968-1997


*** Use Mobile6/UDOT (UM6) adjusted VMT Fraction in Mobile6 format **************

SCENARIO RECORD    : DB1996w
CALENDAR YEAR      : 1996
ALTITUDE           : 2
*PARTICLE SIZE     : 10.0
*PARTICULATE   EF            :   PMGZML.CSV   PMGDR1.CSV   PMGDR2.CSV   PMDZML.CSV
PMDDR1.CSV PMDDR2.CSV
DIESEL SULFUR      : 330.00
VMT BY HOUR        : D:\Utes\Emission\HvmtSL96.d
SPEED VMT          : D:\Utes\Emission\Utl_vmt\Db\SvmtDB96.d
VMT BY FACILITY    : D:\Utes\Emission\Utl_vmt\Db\FvmtDB96.d
VMT FRACTIONS      :
0.5955 0.0551 0.1836 0.0565 0.0259 0.0251 0.0026 0.0017
0.0013 0.0052 0.0063 0.0071 0.0252 0.0012 0.0006 0.0071

SCENARIO RECORD    : DB1997w
CALENDAR YEAR      : 1997
ALTITUDE           : 2
*PARTICLE SIZE     : 10.0
*PARTICULATE   EF            :   PMGZML.CSV   PMGDR1.CSV   PMGDR2.CSV   PMDZML.CSV
PMDDR1.CSV PMDDR2.CSV
DIESEL SULFUR      : 330.00
VMT BY HOUR        : D:\Utes\Emission\HvmtSL96.d
SPEED VMT          : D:\Utes\Emission\Utl_vmt\Db\SvmtDB97.d
VMT BY FACILITY    : D:\Utes\Emission\Utl_vmt\Db\FvmtDB97.d
VMT FRACTIONS      :
0.5955 0.0551 0.1836 0.0565 0.0259 0.0251 0.0026 0.0017
0.0013 0.0052 0.0063 0.0071 0.0252 0.0012 0.0006 0.0071

END OF RUN

*==Run Section:  Composite 1998-2003 ===============================
> SLCo. winter COMPOSITE (All roads) 1998-2003

*************************************
* Ouput Commnands - Vehicle Detail   *
*************************************
NO REFUELING       :
EXPRESS HC AS VOC  :

*************************************
* External Conditions (Weather)      *
*************************************
* Use default hourly temperature profile
* Min/Max temperature is 23-45 in winter, 63-98 in summer
```

* Absolute humidity is 26.8 in winter and 51.3 in summmer

ABSOLUTE HUMIDITY : 26.8
MIN/MAX TEMP   : 35. 45.

****
* Fleet Conditions   *
****
* Use Salt Lake Co. 7/2001 vehicle age data

REG DIST   : D:\Utes\Emission\SLage02.d

****
* Activity Commands (VMT, Starts, Trips) *
****
* Use WFRC VMT by hour in scenario section
* Use 28-vehicle Fvmt by year in scenario section
* Use WFRC VMT by speed in scenario section
* Use WFRC composite VMT mix by year in scenario section
* Use default weekday trip length profiles

*WE DA TRI LEN DI   : F:\SHARED\JORY\Mobile62\Conform\WDTL_96.d

****
* State Programs (County I/M & ATP)   *
****
I/M DESCRIPT FILE : D:\Utes\Emission\SL9850to.d

*Define SLCo ATP Program - Begin ATP 1984, covers models 1968-2050,
*test all vehicle types (14), place holder "1", annual test,
*96% compliance, all inspections but "lead test".

ANTI-TAMP PROG   :
84 68 50 22222 22222222 2 11 096. 22212222
I/M CREDIT FILE   : D:\Utes\Emission\Tech12.d

****
* Fuel Commands   *
****
*Conventional Gasoline West (3), winter RVP = 12.1, summer RVP = 7.8

FUEL PROGRAM   : 3
FUEL RVP   : 12.1

*==Scenario Section: Composite 1998-2003 ==============================
> SLCo. winter, Composite (All roads) 1998-2003

*** Use Mobile6/UDOT adjusted VMT Fraction in Mobile6 format **************

SCENARIO RECORD   : DB1998w

CALENDAR YEAR : 1998
ALTITUDE : 2
*PARTICLE SIZE : 10.0
*PARTICULATE EF : PMGZML.CSV PMGDR1.CSV PMGDR2.CSV PMDZML.CSV PMDDR1.CSV PMDDR2.CSV
DIESEL SULFUR : 330.00
VMT BY HOUR : D:\Utes\Emission\HvmtSL96.d
SPEED VMT : D:\Utes\Emission\Utl_vmt\Db\SvmtDB98.d
VMT BY FACILITY : D:\Utes\Emission\Utl_vmt\Db\FvmtDB98.d
VMT FRACTIONS :
0.5367 0.0646 0.2152 0.0663 0.0306 0.0261 0.0026 0.0019
0.0014 0.0056 0.0067 0.0074 0.0264 0.0012 0.0006 0.0067

SCENARIO RECORD : DB1999w
CALENDAR YEAR : 1999
ALTITUDE : 2
*PARTICLE SIZE : 10.0
*PARTICULATE EF : PMGZML.CSV PMGDR1.CSV PMGDR2.CSV PMDZML.CSV PMDDR1.CSV PMDDR2.CSV
DIESEL SULFUR : 330.00
VMT BY HOUR : D:\Utes\Emission\HvmtSL96.d
SPEED VMT : D:\Utes\Emission\Utl_vmt\Db\SvmtDB99.d
VMT BY FACILITY : D:\Utes\Emission\Utl_vmt\Db\FvmtDB99.d
VMT FRACTIONS :
0.5367 0.0646 0.2152 0.0663 0.0306 0.0261 0.0026 0.0019
0.0014 0.0056 0.0067 0.0074 0.0264 0.0012 0.0006 0.0067

SCENARIO RECORD : DB2000w
CALENDAR YEAR : 2000
ALTITUDE : 2
*PARTICLE SIZE : 10.0
*PARTICULATE EF : PMGZML.CSV PMGDR1.CSV PMGDR2.CSV PMDZML.CSV PMDDR1.CSV PMDDR2.CSV
DIESEL SULFUR : 330.00
VMT BY HOUR : D:\Utes\Emission\HvmtSL96.d
SPEED VMT : D:\Utes\Emission\Utl_vmt\Db\SvmtDB00.d
VMT BY FACILITY : D:\Utes\Emission\Utl_vmt\Db\FvmtDB00.d
VMT FRACTIONS :
0.5155 0.0682 0.2268 0.0699 0.0322 0.0262 0.0026 0.0020
0.0015 0.0057 0.0068 0.0075 0.0267 0.0013 0.0006 0.0065

SCENARIO RECORD : DB2001w
CALENDAR YEAR : 2001
ALTITUDE : 2
*PARTICLE SIZE : 10.0
*PARTICULATE EF : PMGZML.CSV PMGDR1.CSV PMGDR2.CSV PMDZML.CSV PMDDR1.CSV PMDDR2.CSV
DIESEL SULFUR : 330.00
VMT BY HOUR : D:\Utes\Emission\HvmtSL96.d
SPEED VMT : D:\Utes\Emission\Utl_vmt\Db\SvmtDB01.d
VMT BY FACILITY : D:\Utes\Emission\Utl_vmt\Db\FvmtDB01.d

VMT FRACTIONS :
0.4982 0.0710 0.2367 0.0730 0.0335 0.0263 0.0026 0.0021
0.0015 0.0057 0.0068 0.0075 0.0268 0.0013 0.0006 0.0064

SCENARIO RECORD : DB2002w
CALENDAR YEAR : 2002
ALTITUDE : 2
*PARTICLE SIZE : 10.0
*PARTICULATE EF : PMGZML.CSV PMGDR1.CSV PMGDR2.CSV PMDZML.CSV PMDDR1.CSV PMDDR2.CSV
DIESEL SULFUR : 330.00
VMT BY HOUR : D:\Utes\Emission\HvmtSL96.d
SPEED VMT : D:\Utes\Emission\Utl_vmt\Db\SvmtDB01.d
VMT BY FACILITY : D:\Utes\Emission\Utl_vmt\Db\FvmtDB01.d
VMT FRACTIONS :
0.4842 0.0734 0.2447 0.0754 0.0347 0.0264 0.0026 0.0020
0.0015 0.0057 0.0069 0.0075 0.0269 0.0013 0.0006 0.0062

SCENARIO RECORD : DB2003w
CALENDAR YEAR : 2003
ALTITUDE : 2
*PARTICLE SIZE : 10.0
*PARTICULATE EF : PMGZML.CSV PMGDR1.CSV PMGDR2.CSV PMDZML.CSV PMDDR1.CSV PMDDR2.CSV
DIESEL SULFUR : 330.00
VMT BY HOUR : D:\Utes\Emission\HvmtSL3.d
SPEED VMT : D:\Utes\Emission\Utl_vmt\Db\SvmtDB03.d
VMT BY FACILITY : D:\Utes\Emission\Utl_vmt\Db\FvmtDB03.d
VMT FRACTIONS :
0.4695 0.0758 0.2528 0.0778 0.0358 0.0265 0.0026 0.0021
0.0015 0.0059 0.0070 0.0076 0.0271 0.0013 0.0006 0.0061

END OF RUN

*==Run Section: Composite 2004-2050 ==============================
> SLCo. winter COMPOSITE (All roads) 2004-2050

****
* Ouput Commnands - Vehicle Detail *
****
NO REFUELING :
EXPRESS HC AS VOC :

****
* External Conditions (Weather) *
****
* Use default hourly temperature profile
* Min/Max temperature is 23-45 in winter, 63-98 in summer
* Absolute humidity is 26.8 in winter and 51.3 in summmer

ABSOLUTE HUMIDITY : 26.8

```
MIN/MAX TEMP       : 35. 45.

**************************************
* Fleet Conditions                   *
**************************************
* Use Salt Lake Co. 7/2001 vehicle age data

REG DIST           : D:\Utes\Emission\SLage02.d

******************************************
* Activity Commands (VMT, Starts, Trips) *
******************************************
* Use WFRC VMT by hour in scenario section
* Use 28-vehicle Fvmt by year in scenario section
* Use WFRC VMT by speed in scenario section
* Use WFRC composite VMT mix by year in scenario section
* Use default weekday trip length profiles

*WE DA TRI LEN DI   : F:\SHARED\JORY\Mobile62\Conform\WDTL_96.d

****************************************
* State Programs (County I/M & ATP)    *
****************************************
I/M DESCRIPT FILE  : D:\Utes\Emission\SL9850to.d

*Define SLCo ATP Program - Begin ATP 1984, covers models 1968-2050,
*test all vehicle types (14), place holder "1", annual test,
*96% compliance, all inspections but "lead test".

ANTI-TAMP PROG     :
84 68 50 22222 22222222 2 11 096. 22212222
I/M CREDIT FILE    : D:\Utes\Emission\Tech12.d

********************************
* Fuel Commands                *
********************************
*Conventional Gasoline West (3), winter RVP = 12.1, summer RVP = 7.8

FUEL PROGRAM       : 3
FUEL RVP           : 12.1


*==Scenario Section: Composite 2004-2050 ==============================
> SLCo. winter, Composite (All roads) 2004-2050


SCENARIO RECORD    : DB2004w
CALENDAR YEAR      : 2004
ALTITUDE           : 2
*PARTICLE SIZE     : 10.0
```

*PARTICULATE EF : PMGZML.CSV PMGDR1.CSV PMGDR2.CSV PMDZML.CSV PMDDR1.CSV PMDDR2.CSV
DIESEL SULFUR : 330.00
VMT BY HOUR : D:\Utes\Emission\HvmtSL4.d
SPEED VMT : D:\Utes\Emission\Utl_vmt\Db\SvmtDB03.d
VMT BY FACILITY : D:\Utes\Emission\Utl_vmt\Db\FvmtDB03.d
VMT FRACTIONS :
0.4550 0.0783 0.2608 0.0804 0.0370 0.0266 0.0026 0.0021
0.0016 0.0059 0.0070 0.0076 0.0272 0.0013 0.0006 0.0060

SCENARIO RECORD : DB2005w
CALENDAR YEAR : 2005
ALTITUDE : 2
*PARTICLE SIZE : 10.0
*PARTICULATE EF : PMGZML.CSV PMGDR1.CSV PMGDR2.CSV PMDZML.CSV PMDDR1.CSV PMDDR2.CSV
DIESEL SULFUR : 330.00
VMT BY HOUR : D:\Utes\Emission\HvmtSL4.d
SPEED VMT : D:\Utes\Emission\Utl_vmt\Db\SvmtDB05.d
VMT BY FACILITY : D:\Utes\Emission\Utl_vmt\Db\FvmtDB05.d
VMT FRACTIONS :
0.4411 0.0807 0.2687 0.0828 0.0380 0.0267 0.0026 0.0021
0.0016 0.0059 0.0070 0.0077 0.0273 0.0013 0.0006 0.0059

SCENARIO RECORD : DB2006w
CALENDAR YEAR : 2006
ALTITUDE : 2
*PARTICLE SIZE : 10.0
*PARTICULATE EF : PMGZML.CSV PMGDR1.CSV PMGDR2.CSV PMDZML.CSV PMDDR1.CSV PMDDR2.CSV
DIESEL SULFUR : 330.00
VMT BY HOUR : D:\Utes\Emission\HvmtSL6.d
SPEED VMT : D:\Utes\Emission\Utl_vmt\Db\SvmtDB05.d
VMT BY FACILITY : D:\Utes\Emission\Utl_vmt\Db\FvmtDB05.d
VMT FRACTIONS :
0.4271 0.0831 0.2767 0.0853 0.0392 0.0267 0.0026 0.0021
0.0016 0.0059 0.0070 0.0077 0.0273 0.0013 0.0006 0.0058

SCENARIO RECORD : DB2007w
CALENDAR YEAR : 2007
ALTITUDE : 2
*PARTICLE SIZE : 10.0
*PARTICULATE EF : PMGZML.CSV PMGDR1.CSV PMGDR2.CSV PMDZML.CSV PMDDR1.CSV PMDDR2.CSV
DIESEL SULFUR : 330.00
VMT BY HOUR : D:\Utes\Emission\HvmtSL6.d
SPEED VMT : D:\Utes\Emission\Utl_vmt\Db\SvmtDB07.d
VMT BY FACILITY : D:\Utes\Emission\Utl_vmt\Db\FvmtDB07.d
VMT FRACTIONS :
0.4120 0.0857 0.2852 0.0879 0.0404 0.0267 0.0026 0.0021
0.0017 0.0060 0.0070 0.0077 0.0273 0.0014 0.0006 0.0057

SCENARIO RECORD : DB2008w
CALENDAR YEAR : 2008
ALTITUDE : 2
*PARTICLE SIZE : 10.0
*PARTICULATE EF : PMGZML.CSV PMGDR1.CSV PMGDR2.CSV PMDZML.CSV PMDDR1.CSV PMDDR2.CSV
DIESEL SULFUR : 330.00
VMT BY HOUR : D:\Utes\Emission\HvmtSL6.d
SPEED VMT : D:\Utes\Emission\Utl_vmt\Db\SvmtDB07.d
VMT BY FACILITY : D:\Utes\Emission\Utl_vmt\Db\FvmtDB07.d
VMT FRACTIONS :
0.3969 0.0882 0.2937 0.0905 0.0416 0.0269 0.0026 0.0022
0.0017 0.0060 0.0070 0.0077 0.0274 0.0013 0.0006 0.0057

SCENARIO RECORD : DB2009w
CALENDAR YEAR : 2009
ALTITUDE : 2
*PARTICLE SIZE : 10.0
*PARTICULATE EF : PMGZML.CSV PMGDR1.CSV PMGDR2.CSV PMDZML.CSV PMDDR1.CSV PMDDR2.CSV
DIESEL SULFUR : 330.00
VMT BY HOUR : D:\Utes\Emission\HvmtSL6.d
SPEED VMT : D:\Utes\Emission\Utl_vmt\Db\SvmtDB10.d
VMT BY FACILITY : D:\Utes\Emission\Utl_vmt\Db\FvmtDB10.d
VMT FRACTIONS :
0.3828 0.0906 0.3017 0.0930 0.0427 0.0269 0.0026 0.0022
0.0017 0.0060 0.0070 0.0077 0.0275 0.0014 0.0006 0.0056

SCENARIO RECORD : DB2010w
CALENDAR YEAR : 2010
ALTITUDE : 2
*PARTICLE SIZE : 10.0
*PARTICULATE EF : PMGZML.CSV PMGDR1.CSV PMGDR2.CSV PMDZML.CSV PMDDR1.CSV PMDDR2.CSV
DIESEL SULFUR : 330.00
VMT BY HOUR : D:\Utes\Emission\HvmtSL6.d
SPEED VMT : D:\Utes\Emission\Utl_vmt\Db\SvmtDB10.d
VMT BY FACILITY : D:\Utes\Emission\Utl_vmt\Db\FvmtDB10.d
VMT FRACTIONS :
0.3696 0.0929 0.3092 0.0953 0.0438 0.0269 0.0026 0.0021
0.0016 0.0060 0.0071 0.0077 0.0276 0.0014 0.0006 0.0056

END OF RUN